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I. FAMINES IN INDIA.

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FEW, if any, countries of the world have escaped the scourge of famine at one time or another of the period of their national existence. The earliest calamities of this kind, of which any records exist, occurred in Palestine and the surrounding countries, in the days of Abraham, Isaac, and Jacob; but little is known of the numbers and extent of the famines that occurred in the world before the commencement of the Christian era, those historians who have recorded such events being few and far between, and the information they have furnished concerning them is but scanty. It is not intended, on the present occasion, to attempt to trace the famines of the world, so far as the materials for that purpose might be available, but to confine our observations and remarks to those that have, in times past, desolated our Empire in the East. Famines in Europe are not now of such frequent occurrence as in bygone centuries,—indeed they may be said to have altogether ceased; but in India they appear to occur more frequently than of old, and in greater severity than formerly. In making this remark, however, it must be observed that there is no sure evidence that such is the case absolutely, but there certainly is tolerably reliable proof that—in the East Indies, at least—they have increased in severity within the last hundred years; but previously to 1770 the records of Indian famines are scanty, and probably not wholly reliable as to details. A more important question for consideration than the mere frequency of famines is, however, the cause of famines, and, consequent upon that, the best means to be employed for meeting

them, or for counteracting, to a greater or lesser degree, their effects. Whatever may be the primary cause, or causes, of the meteorological disturbances which interfere with the usual amount of rain falling in any year, it seems very questionable whether human ingenuity will be able to devise means for regulating atmospheric phenomena; nevertheless it is certain that the advancement of civilisation, with its attendant circumstances, does, in some way or another, not only render a land less liable to the scourge of famine, but it also provides the means for mitigating its effects on the occurrence of a visitation of this nature. The events of recent years lead, however, to the painful conclusion that—so far as India is concerned—practical civilisation has gone a very little way, when we find that hardly more than a first step has yet been taken in the successful application of our knowledge and material resources to warding off calamities such as these. In India the amount of annual rainfall varies considerably in different localities; for whilst Sind and parts of Rajputana and the Punjab are comprised within an arid zone, and have an average rainfall of less than 10 inches, the central table-land of the Peninsula, known as the Deccan, and the greater part of Mysore, have a fall of less than 30 inches, in the extreme east the amount of rain reaches from 80 to upwards of 100 inches. The absolute insufficiency of the rainfall, within the arid zone, to support cultivation, has led the inhabitants of those parts, from the very earliest date, to make up for the deficiency by turning the waters of the Indus and its feeder rivers over the land during the season of agriculture. These parts may therefore be fairly said to be placed beyond serious risk of famine through drought, the rivers whence their means of irrigation are obtained being fed by the perpetual snows of the Himalayas; and even though their waters may occasionally partially fail, it appears that, when this is the case, the inconvenience caused is very limited and local, and of no serious moment. In Southern India the enormous numbers of tanks, which owe their existence to former dynasties, testify to the necessity that has, for ages past, existed for the careful husbanding of water for the purposes of irrigation.

The precautions taken in those parts where the rainfall is but limited, to provide water for the soil, being, as they were, unquestionably undertaken to provide against loss of crops, and therefore against famine, it is not unreasonable to suppose that the necessity of these works of artificial irrigation was impressed upon the rulers, by whom they

were constructed, by the hard lesson of experience through drought and famine. Although it is certain that India has been subjected to famines from the very earliest ages, very little information now exists regarding those that occurred more than 108 years ago, but from that date there are to be found tolerably accurate particulars of all that have since taken place. Ferishta, the Persian historian, mentions a famine in India during the reign of one Jei-chund, who was Emperor of India between the years 503 and 443 B.C. This is probably the earliest of which any record exists, and after it there occurs a lapse of nearly 1500 years before the next famine mentioned, which, it is stated, took place in 1022 A.D., a year remarkable for a great drought and famine in Hindustan, as well as in many other parts of the world. This was followed, after an interval of about thirty years, by a seven years' drought in "Ghor," which was accompanied by a considerable loss of life, both amongst men and animals. The next famine mentioned occurred in 1291, in the neighbourhood of Delhi, where no rain fell for a whole year, and the same part appears to have been again visited with a similar calamity in the year 1342. Two years later there was a famine in the Deccan. In 1413 Delhi was once more subjected to scarcity through drought, which appears to have been principally felt in the country between the Ganges and Jumna Rivers. The next famine recorded is said to have occurred in Hindustan about the year 1495, but neither its extent nor the particular localities affected are more specially described. After this a considerable interval occurs, no subsequent dearth being mentioned until the year 1661. This famine is said to have prevailed in different parts of India, and the Emperor Aurungzebe took such measures as were within his power to alleviate the distress of his subjects. He remitted the taxes that were due; he employed those already collected in the purchase of corn, which was distributed among the poorer classes; and he expended immense sums out of the treasury in conveying grain by land, as well as by water, into the interior provinces, from Bengal, and from the countries which lie on the five branches of the Indus, which suffered less on account of the great rivers by which they are watered. The grain so conveyed was purchased, at any price, with the public money, and it was re-sold at a very moderate rate, whilst the poorer people were supplied, at fixed places, with a certain quantity without any consideration whatever. By these measures, it is stated, whole provinces were

delivered from impending destruction, and many millions of lives were saved.

This brings us to the end of the famines regarding which information is obtainable from Mahommedan sources. The Hindoos, with their well-known contempt for history, have recorded nothing of a similar nature on the subject of famines in the peninsula of India, and no light can therefore now be thrown upon the question as to how far that part of the Indian Empire was, in early times, subject to such visitations.

With the great famine of 1769-70 we enter upon the commencement of a period from which the principal famines of India have been chronicled by European historians; but it cannot be said with certainty that a full account of these calamities, for the whole of India, began to be recorded previously to 1860-61, in which year parts of the North-western Provinces and the Punjab suffered severely from drought, owing to the failure of the usual rains. For this reason there can be little doubt that famines of greater or less severity have occurred, within the past hundred years, especially in the more remote parts of the Empire, of which no particulars now are to be found; and there are strong reasons for believing that this has been the case, as legends exist, amongst some of the older native inhabitants, of great scarcity in certain years, and of its attendant calamities to the people, of which, however, no more reliable information can now be obtained. Without attempting to enter into detail regarding the famines of the past century—which would occupy far more space than could fairly be claimed for that purpose—a brief account of some of the most noted of these visitations will form an appropriate introduction to a consideration of their causes, so far as this has as yet been ascertained by scientific research, and of the best means to be adopted with a view to relieve the districts affected from their attendant consequences.

Subsequently to that in Northern India, of 1769-70, the next severe famine visited the Carnatic, and the Settlement of Madras in the years 1781 to 1783, which was, to a great extent, brought about by the devastations caused by Hyder Ali's armies. The Settlement of Madras was reduced to such straits for food that Government found it necessary to take steps for regulating the supplies of grain, and in January, 1782, a public subscription was raised for the relief of the poor, from which originated the institution for the relief of the Native poor, known as the Monegar Choultry. In 1783-84 certain parts of Upper India are said to have

been seriously affected by drought, but, as the countries which suffered most were not then subject to British rule, very little information is obtainable relative to that famine. In the years 1790 to 1792 there was a very serious drought in the Madras Presidency, and at an early period Government suspended the import and transit duties on all kinds of grain and provisions, and themselves imported grain from Bengal. Rice was distributed gratuitously by Government, and relief was afforded by employing the poor on public works. In 1824-25 Madras was again visited with famine, which was caused by failure of rain in most of the provinces of that Presidency, and more particularly in the Carnatic and Western Districts; numbers of starving poor flocked into Madras, and relief establishments were formed for them partly by private charity and partly at the expense of Government. The year 1837-38 was long afterwards remembered in consequence of the failure of rain, which brought scarcity and famine to the North-western Provinces and to Rajputana. No sooner had the serious pressure of famine begun to be felt than the ordinary bonds of society seemed to be broken by it. Beginning at Rohilkhund, the population gathered into bands for plunder, and attacked the grain stores in the larger villages and towns. This calamity was of such intensity and magnitude as to have been almost unmanageable, and the deaths from starvation alone are believed to have exceeded 800,000. Relief Committees were formed for the distribution of private charity, and Government expended very large sums in the employment of the population on relief works, in addition to which, before February, 1838, no less a sum than £600,000, on account of revenue, had been remitted.

The next serious famine seems to have occurred in 1860-61, the effects of which extended over the Punjab and parts of the North-western Provinces, affecting districts having a population of about 13 millions, and a cultivated area, in ordinary seasons, of 12,293,000 acres, of which 4,457,000 acres were thrown out of cultivation during the famine period. Up to the 30th April, 1861, as many as 26 central and 75 district relief-houses had been established in the famine districts, at which, on the average, 80,000 people were relieved daily, and, besides this, a series of special relief works was organised for the relief of the able-bodied poor, upon which 143,500 people were, on the average, daily employed. Owing to the better means of communication, greater promptness in anticipating the effects of the drought, and improved organisation for dealing with the distress, the

famine of 1860-61 was a much less awful calamity than that of 1837-38. Four years later—viz., in 1865-66—Orissa, Bengal, and Behar were visited by famine, owing to the premature cessation of the rains throughout the Lower Provinces of Bengal, in the middle of September, 1865. In Behar this had been preceded by two years of bad crops. The general distress amongst the lower classes was manifested by a large increase in crime; village granaries were burnt and plundered, and extensive grain robberies—committed solely for the purpose of obtaining food—were of constant occurrence. In June committees were formed, funds raised for the relief of those incapable of work, and employment was provided for the able-bodied on public works.

Historical records show that Orissa has at various times suffered from terrible famines. Great famines are said to have occurred in the fourteenth, fifteenth, and sixteenth centuries of our era. The great famine of Bengal of 1770 was felt grievously in Orissa, and a few years later, in 1774-75, another great scarcity is said to have occurred. The last great famine, of the traditions of which the old men speak, was in 1792-93, in the time of the Mahrattas; but none of a general character happened in the present century before the year 1865-66. For the two preceding years the crops had been below the average, and the failure of rain in this year was immediately followed by serious famine. It was very soon apparent that the consequent distress could not be effectually met by local private charity; public works on a large scale were shortly put in hand to give employment to the starving population, who were paid the ordinary rate of money wages. Notwithstanding repeated applications for permission to import rice, on the part of Government, owing to the failure of private enterprise to supply the necessary food to the affected districts, they were persistently negatived, and the consequence was that the works undertaken to relieve the distressed people were to a very great degree inoperative, for want of rice to feed the labourers. As the famine increased in intensity Relief Committees were formed, by whom subscriptions were raised and food distributed. At length public works and relief works were stopped for want of food, and Government then sanctioned the importation of rice for the relief of the sufferers, and in July centres were established for the distribution of cooked food.

In 1866 the Madras Presidency was also visited by drought. The two years preceding had been generally

unfavourable to agriculture, but it was not till October, 1865, that symptoms of distress began to show themselves, and in the following month Government sanctioned the employment of the poorer classes on public works. By March, 1866, the distress had increased, and many relief depôts were opened by private subscription at several places in the Ganjam district. In June the Bengal Government sanctioned a grant of Rs. 20,000 from the balance of the North-west Provinces Famine Relief Fund, which was chiefly expended in grain, on the public account, and despatched to Ganjam. Considerable funds were also raised locally, and in Madras, for the relief of the distress of that district, and the Madras Government sanctioned an expenditure of Rs. 3000 per mensem, from the State Funds, for the same purpose. In July a General Famine Relief Committee was formed to collect subscriptions to alleviate the distress, and Government promised to make contributions to the Relief Fund equivalent in amount to the private subscriptions which might be raised for the purpose, and sanction was, at the same time, given for the employment of the able-bodied among the sufferers on public works. The years 1868 to 1870 were noted for an extensive famine which ranged from Behar, over great parts of the North-west Provinces, the Punjab, and Rajputana, and was caused by the failure of the harvest of 1868 following upon an unfavourable season in the preceding year. An untimely fall of rain in the autumn of 1869 caused great anxiety, and the crops proved very short. Generally speaking the famine had disappeared in the North-west Provinces by October, 1869; but in Ajmir and Mhairwarra a plague of locusts succeeded the drought, and prolonged the sufferings in those parts until the close of March, 1870, or even later.

The next famine visited Bengal and Behar, in the years 1873-74. In 1872 the rain was somewhat deficient, and the following year was also a dry one, almost beyond precedent, and what rain did fall was unfortunately distributed; south of the Ganges it was excessive, but in North Behar, and almost the whole of Bengal, the rain was far below the average. Coupled with deficient rainfall, the monsoon of 1873 was abnormally hot. The famine reached its culminating point in April and May, 1874, and it was completely over by about October, 1874. The experience gained in dealing with previous famines was of great value on this occasion, and enabled Government successfully to meet the calamity and organise systems of relief. Tolls were removed from ferries and roads along the chief routes for

grain transport; assistance was given to *bonâ fide* importers of grain, with loans of money without interest; a number of relief works were commenced, on which wages to labourers were authorised to be paid in grain whenever the local price reached famine rates; storehouses for Government grain were constructed on all the chief works; and other facilities were provided for the transport and distribution of food through the ordinary channels of trade, or through the agency of Relief Committees.

Little need be said here of the recent great famine in Madras and Bombay. In 1875 the season was in many places unpropitious, and in the following year the south-west monsoon was deficient throughout the greater part of the Madras Presidency and in portions of Bombay. In Madras, famine first threatened in July, 1876, whilst in October the whole of the nine districts of the Bombay Deccan were seriously threatened, nearly all the monsoon crops having perished, and there having been no later rains to admit of sowing the rabi. The spring and summer rains again failed in 1877, and the distress became still greater generally throughout the affected districts. The relief measures adopted by Government, and through private agency, have so recently formed the subject of report and discussion in the daily papers that any repetition on that point seems unnecessary here.

We now turn from the foregoing brief historical summary to a consideration of the scientific side of the question. This divides itself into two heads, viz. (1), the causes of famines; and (2), the means to be adopted for averting them, on the one hand, or of mitigating their effects, on the other.

A close examination into all the circumstances of past famines shows that they have not been caused by the failure of rains in one season only. The stocks of grain ordinarily reserved in the country would appear to be sufficient, generally, to carry the people over a single season of drought, and consequently of deficient harvest; but when a famine occurs it has been the result of one or two consecutive bad seasons, followed by one of unusual drought; and experience thus teaches that the probable advent of a famine may be anticipated, with at any rate sufficient exactness to enable precautionary measures to be adopted in anticipation, with a view to meeting the emergency should it arise. Fortunately, India is capable of supplying far more food than is required for the maintenance of her populations, even in ordinary seasons, and as droughts occur only locally, and

have never hitherto been known to affect the entire Empire at one and the same time, the surplus produce of one district is always available to supply the wants of others when famine occurs in them. It is a point worthy of remark that severe droughts in Northern India have, on several occasions, followed closely upon distress similarly caused in the Peninsula of India: thus, the Madras famine of 1781 to 1783 was followed by one which affected Bengal, the North-west Provinces, and the Punjab, in 1783-84; the failure of rains which resulted in scarcity in many of the provinces of the Madras Presidency, in 1824-25, was followed by a similar calamity in the North-west Provinces in the succeeding year. The "Guntoor" famine of 1833 preceded, only by a few years, one which affected the North-west and Lower Provinces of Bengal in 1837-38, and the Madras famine of 1866 was very closely followed by one in the North-west Provinces and the Punjab in 1868 to 1870.

Although no absolute famine has as yet threatened in Northern India, following upon the recent disastrous and long-continued calamity in the Peninsula, there are not wanting signs which are causing no small amount of anxiety with regard to crop prospects in other parts of the Empire.

An attempt has been made to connect the occurrence of severe famines in India with the periods of maximum sun spots, the reason for which has, however, never been very clearly enunciated; neither has it been shown why such solar phenomena should affect one part of the world and not others, or why the influences—whatever they may be—should fall sometimes upon one part of India and sometimes upon another; indeed, the more this theory is investigated the more untenable it appears to be; but, even if it could be established, it is to be feared that, with our present limited knowledge of meteorological phenomena, but little benefit could be derived from a knowledge of the fact that certain solar disturbances did influence terrestrial meteorology.

Famines in India, excepting those of purely local origin and extent, may be said to be caused by failure of the usual rains; failure, that is, not always in regard to quantity only, but often also to distribution, for sometimes the rain will fall so heavily at the commencement of the monsoon season as to render agricultural operations impossible, and fail altogether when the seed is at last sown and moisture is required to bring the plant to maturity. Also, when there has been a light fall only at the sowing season, excessive

storms will sometimes destroy the ripening crops before they can be gathered in. These are, however, rather exceptional cases, and, as a rule, failure in the quantity of rainfall, rather than its unequal distribution, is the primary cause of famine in India. Local famines have been caused by excessive floods in rivers, and by blight. The former, as we shall presently see, is in a great measure capable of being remedied, but for the latter we are unable at present to suggest any practical cure.

The question as to how famines may be absolutely averted is one upon which speculation may be allowed to indulge itself, but absolute proof is wanting. England, Ireland, and most parts of Europe were, in centuries past, visited by many and severe famines, of much greater frequency than at the present day; but, with the advancement of civilisation, their tendency to occur has most sensibly diminished. In dwelling upon this point it is of importance to distinguish between the less frequency of failures of crops and the altered conditions of European countries, in consequence of which failure of crops in any one country would not necessarily mean famine, in the same sense as it once would have done; but it may be observed that, with the improvement of Western countries in this respect, the Eastern hemisphere appears to have become more subject to severe droughts than heretofore, and not only is this the case absolutely, but these visitations—so far as the East Indies are concerned—have of late years shown an evident tendency to increase in severity and frequency, the causes of which are at present unappreciated, but they are certainly deserving of the most serious consideration and investigation by scientific men, no less than by Government. A theory has of late gained ground amongst certain enquirers into this subject that the amount of rainfall is influenced by forests, and that, in countries subject to drought, all that is necessary is to plant trees in order to restore the proper seasons of rainfall. How far this is supported by facts is, however, at present uncertain. We have instances of barren wastes in Africa, Sind, and elsewhere, upon which rain hardly ever falls; whilst, on the other hand, there are the forest-clad mountains of Northern and Western India, upon which the amount of precipitation is excessively heavy. These may be taken as two extremes; but although illustrating the facts that in certain places where there is no foliage rain is almost unknown, and that an abundance of rain and dense forests occur together, they do not help to solve the problem to what extent denudation of forest tracts may be permitted

without interfering with the average annual rainfall. From meteorological observations taken in the Madras Presidency it does not appear that this point has yet been reached, but it is nevertheless contended by some that the destruction of trees in the forests of Southern India has already been carried to an extent absolutely injurious to the interests of cultivation. If this be the case it follows that, although the quantity of rainfall may not have been absolutely affected, its periodic distribution may nevertheless be rendered less certain and constant, the consequences of which would be only in a small degree less disastrous to agriculture than absolute drought; but on this point, also, careful observations over extensive areas, and for a succession of years, are necessary before any positive decision can be pronounced on the subject. In one respect the influence of trees upon rain, after it has fallen, has been well ascertained, and their importance to the country in that respect most fully established. In the absence of trees upon slopes and hill-sides the rainfall rapidly rushes over the surface of the land to the nearest drainage lines, in the steeper places carrying with it the soil from the surface, destroying at one and the same time the fertility of the land, and choking up the drainage channels of the country; also, in the absence of the check to this rapid surface drainage, the rain-water over large areas is rapidly precipitated into the nearest rivers, filling them beyond the capacities of their channels, and so causing floods in their lower reaches, especially where, emerging from the hills, they enter upon the alluvial plains. By the presence of trees these effects are prevented; the rainfall is arrested in its flow over the soil, and being retained by lower growth, and the roots of trees, finds its way into the soil, and thence by degrees, through underground channels, into the rivers, whilst a considerable portion is retained in the substrata, replenishing springs and filling wells.

So far as experience at present teaches there do not appear to exist any known methods by the adoption of which famines can be actually averted, but they appear to die out before the advance of civilisation, the effects of which seemingly react in numberless ways upon the physical conditions of a country, which, in turn, exercise no inconsiderable change in the meteorological state of the atmosphere. Many of these effects of civilisation are sufficiently known to enable them to be defined, and although they may doubtless be put into operation, upon a small scale, and in detached localities throughout India, by the agency of

Government, it would be hopeless to expect the full benefits of the necessary changes to be felt, as they have been in Europe, in practically rendering famines impossible, until the populations themselves are sufficiently advanced in moral and intellectual civilisation to appreciate the truths involved in these measures, and endowed with sufficient energy to carry them thoroughly into effect. It is only when all the known means for mitigating the effects of famines have been well established throughout the country —or, in other words, when civilisation, as it exists in the Western Hemisphere, is finally and fully established in the East—that there can be any serious hope entertained that the calamitous visitations of famine, now so common in India, will cease to occur.

The three principal measures to be adopted with a view to mitigate the effects of famines are—(1.) The provision of a complete system of communications throughout the country. (2.) Improvements in the system of agriculture generally. (3.) The construction of artificial irrigation works wherever they may be practicable. With regard to the first, viz., communications, there exist two rival plans, each of which has its advocates; the one plan comprising railways as the chief arterial system of the country; and the other, lines of water communication. It can hardly be necessary to say much upon this question. It is a fact that the whole of India has never yet, within historic periods, been subjected to drought and famine throughout its length and breadth at one and the same time; it already grows more food grain than is required for the supply of its populations under ordinary circumstances, and it exports wheat largely to this country, as well as rice. At no time, it is believed, has there been an actual scarcity of food in the country, and it necessarily follows that suitable means of communication alone are necessary to enable the surplus produce of one district to be transported to another, where, by reason of drought or other causes, the supply may be deficient. In certain places, and under favourable conditions, no doubt grain—in common with all other bulky articles—may be more cheaply conveyed by water carriage than by railways; and, wherever a never-failing supply of water can be relied upon, every encouragement should undoubtedly be given to improve what may be styled the *natural* highways of the country, viz., its rivers, and in certain circumstances it may even be desirable to render irrigation canals suitable for navigation. Experience on this latter point, in India, does not support the supposition

that expenditure incurred for the purpose will be directly remunerative; but then, also, neither are roads; and the arguments that are used in favour of spending money on the latter class of works apply also to the former. Means of communication in a country is the first necessity for the introduction of civilisation, which almost naturally follows upon the free communication and interchange of goods and ideas between people. As civilisation becomes more advanced, improved means of communication are demanded, and have to be supplied. In India, Western civilisation and Indian semi-barbarism meet, and the requirements of the latter are being supplied upon a scale calculated by the experiences of the former; and an advanced form of civilisation, in the shape of communications, is thus being forced upon a people not yet educated up to the extent of their country's requirements. Nevertheless, railways may be said to have proved not only a decided success in India, but an absolute necessity in times of famine. No other means of transport could have possibly met the recent requirements of Southern India; and the experience gained during the past two years, as to the value of the iron road, may be expected to lead, in the immediate future, to a large extension of the railway systems in that country. What neither navigable channels nor country roads could have accomplished has been done by railways, and the immense amount of food which they have been instrumental in conveying into the famine-stricken districts has proved the means of saving, probably, some millions of people from starvation. It is, therefore, by the judicious extension of railways, primarily, that the principal movements of food will for the future be conducted, and by maintaining an even balance—as might be done—between supply and demand, the onerous pressure of famine prices, as they have heretofore been experienced in seasons of drought, should be greatly mitigated, and the occurrence of actual local famine be rendered impossible.

But although a perfect system of communications would thus render absolute famine—such as has been hitherto common in India—impossible, it would contribute nothing towards the avoidance of drought, and the consequent failure of crops. There can, however, be no doubt that, by an improvement in the present system of cultivation, much might be done towards rendering the crops less liable to total destruction in seasons of deficient rainfall, and enabling them better to withstand the effects of drought. Under existing circumstances the contrary appears at present to be

the case; and instead of improvements in this direction, an opinion is prevalent that the land generally is becoming exhausted, and consequently less productive than it formerly was. One reason for this may probably be that, with an increase of population, fresh lands are broken up for cultivation which are generally of only inferior quality, and, with the existing rude state of agriculture, often yield barely sufficient to do more than cover the cost incurred; whilst, with regard to the better soils, the exhausting nature of the tillage is gradually lessening their productive powers. The use of manure is practised in India to a very limited extent, dry crops being generally left entirely without it, and it necessarily follows that the plant food in the soil must be gradually becoming less and less, where everything is taken from it and nothing returned. When a field becomes barren it is thrown out of cultivation and left fallow for two or three years, when the previous system of exhaustive cultivation is again repeated as long as the land will produce sufficient to pay for seed and labour. The general scarcity of manure in India is, in a great measure, attributable to the want of fire-wood, in consequence of which the dung of cattle is used as fuel, instead of being ploughed into the land as manure. The use of manure, especially in a hot and dry country, is not limited to its value as a means of plant food, when it contains organic matter. Mineral manures are, no doubt, limited in their value to this purpose; but it has been ascertained, by careful experiment, that the addition of organic matter to the soil not only increases its power of absorbing moisture from the atmosphere, but makes it more retentive of moisture when once absorbed, and therefore less liable to be desiccated by dry winds and solar heat.

Next after manure, improved ploughing presents a means of greatly benefitting the crops and the fertile properties of the soil. By breaking up the land to a greater depth than is now done, an unexhausted soil will often be disturbed, possessing greater elements of fertility than the worn-out upper stratum on which crops have been grown, perhaps continuously, for hundreds of years past. Besides this, by deepening the loosened surface, the land is rendered more capable of absorbing rainfall, and permitting it to penetrate to the lower strata, to which also the roots of plants are enabled to reach, owing to the breaking up of the hard "pan" which usually underlies the top three or four inches of soil, which now, under the native system of cultivation, alone are disturbed in the so-called process of ploughing.

Subsoil drainage, also, has been proved in India, as in England, to be greatly conducive to good cultivation, and its benefits have been found to be particularly marked in seasons of drought. Dry soil, according to Prof. Liebig, derives its moisture partly from the vapours of water in the air, and partly by absorption from the deeper-lying moist strata, from which a constant distillation of water is taking place towards the surface. By drainage, the water, which rises by capillary attraction, being placed at a greater depth, the dry soil now derives from the lower strata a quantity of moisture in the form of vapour which supplies the wants of plants, and hence it appears that subsoil drainage renders the land less liable to be seriously affected by drought; and so far it is calculated, under certain conditions, to mitigate the effects which, in India, now invariably follow upon a failure of the usual rains, or even their unequal distribution during the monsoon season.

Another benefit to agriculture would also arise from the more general presence of trees over cultivated areas. In the first place their leaves would furnish material for manure, whilst the dead wood and branches, by supplying means for fuel, would enable the dung of the cattle to be appropriated to its more legitimate use as manure. The influence of trees over climate is also very important. By the process of distillation which is ever taking place in the surface of their leaves the temperature of the surrounding atmosphere is lowered, whilst they also communicate moisture to it owing to the process of evaporation which is constantly taking place through their means. By thus rendering the climate in their immediate vicinity both cooler and moister they contribute greatly to the interests of agriculture, and in only a somewhat lesser degree by the protection which they afford to the crops against wind and storms, and to the soil from evaporation and drought against dry winds and heat.

From whatever point it is viewed, improved agriculture appears well calculated to contribute, in no small degree, towards protection against famines in India, and it will undoubtedly do much to save crops from destruction in seasons of drought, where artificial irrigation is not available. When—from the vicinity of tanks, rivers, or canals—water can be obtained to supply the deficiency of rain, every advantage should undoubtedly be taken of its proximity to protect crops during drought, and to increase the yield in ordinary seasons; but, under any circumstances, the area of land which can be so watered must be but small compared

with the total extent of cultivation throughout the country. Some classes of irrigation works, too, are liable to fail from want of water, at the very time when it is most in demand; and it is only those irrigation works which derive their water from perennial rivers, whose supplies are not wholly dependent upon fluctuating rainfall, which can be relied upon as unfailing sources in times of greatest emergency. In ordinary seasons irrigation works must always prove of great advantage, for by enabling larger crops to be grown than could otherwise be the case they must largely contribute towards the well-being of the cultivators, and, by rendering it possible for them to accumulate wealth, either in the shape of grain or money, they will thereby be enabled the better to endure the strain to which they are subjected in years of famine.

The improvement and extension of communications, whether they be roads, railways, or water navigation channels, and the multiplication of irrigation works wherever they can be constructed, are means within the power of Government to adopt for the protection of the people from the effects of famine, and for the advancement of the general well-being of the country. The multiplication of these, or other great public works, is a matter with which the advancement of the people in intelligence has at present no immediate connection, but as regards improved agriculture the case is far different, and this will, and can, never be introduced generally into the country until the people themselves shall have been raised by education, both moral and intellectual, from their present state to one of more advanced civilisation. Towards this there can be little doubt that railways will contribute more than any other means at present available. The conclusion to be drawn from a careful consideration of all the circumstances of the case is, that there is no immediate remedy against famines possible in India; their effects may be mitigated by judicious treatment locally, but their real cause, being like poison in the human blood, must be dealt with in a patient and scientific manner, and time allowed for the full and free action of western civilisation throughout the entire system, before it can be expected that the medicine will effect a perfect cure, and the East, like the West, be delivered from fear of those visitations which now destroy her children, cripple her resources, and check that advancement in material prosperity which it might be hoped she would otherwise enjoy.

II. THE PROGRESS OF THE DOCTRINE OF DEVELOPMENT.*

AMONG the general public, and even to some extent among men of Science who are not biological specialists, it is too commonly supposed that Evolutionism sprang at once into full maturity from the brain of Mr. Darwin; that Darwinism and Evolutionism are convertible terms; and that the doctrine is accepted with but little scrutiny by the majority of modern naturalists more as an article of faith than a scientific truth. Nothing could be farther from the real state of the case. The theories of Mr. Darwin are regarded as a mere tentative sketch, to be revised, emended, filled in, or even cancelled, as future observation and experiment may dictate. To this process they are being constantly submitted, and the general result may be stated to be that while the belief, or rather the conviction, of the truth of Evolution as "God's mode of Creation" is gaining ground, the precise agencies by which Mr. Darwin supposed such Evolution to be mainly effected are looked upon by many with doubt, or are at least relegated to a more subordinate position.

It is well known that Mr. Darwin, along with many of his more immediate followers, ascribes the development of species as we actually find them to two causes—both slow, gradual, and uniform in their action. These are Natural Selection and Sexual Selection, the former an utterly unconscious, but the latter a conscious, agency. To Sexual —or, as it has been not unhappily styled, Female—Selection he attributes not indeed the origin of any new form of life, but the ornamentation, and especially the colours, of the higher animals, such as the vertebrates and insects, and especially the generally brighter hues and the decorative appendages which characterise the male sex. He argues that the females having for ages past given the preference to the most beautiful males of their respective species, these have had a better chance of leaving a numerous offspring than their less brilliant rivals, and have transmitted their

* Tropical Nature and other Essays. By ALFRED R. WALLACE. (London: Macmillan and Co.)

All the Articles of the Darwin Faith. By the Rev. F. O. MORRIS, B.A. (London: Moffatt, Page, and Co.)

Zur Entwickelungs-Geschichte der Menscheit. By L. GEIGER. (Stuttgart.)

attractions to their male posterity. Thus, by the secular action of this principle, he contends that the gorgeous hues and exquisite designs of the wings of butterflies, the train of the peacock, the secondary wing-feathers of the Argus pheasant, the gorgets and crests of humming-birds, have been elaborated. This hypothesis certainly harmonised with a considerable number of striking facts previously unexplained, and seemed at first glance to agree with many more. Mr. Wallace, however, has long held this portion of Mr. Darwin's views to be erroneous, and brings forward against it certain exceedingly weighty arguments. In an earlier work, with which every naturalist ought to be familiar,* he has shown that in female birds the need of protection, especially during the season of incubation, has repressed those bright colours which would otherwise be produced by general laws in both sexes alike. He now further argues that high colouration, if not directly due to, is yet correlated with, vital intensity. "The very frequent superiority of the male bird or insect in brightness or intensity of colour, even when the general colouration is the same in both sexes, seems to me to be primarily due to the greater vigour and activity and the higher vitality of the male. The colours of an animal usually fade during disease or weakness, while robust health and vigour add to their intensity. This is a most important and suggestive fact, and one that appears to hold universally. In all quadrupeds a dull coat is indicative of ill health or low condition, while a glossy coat and sparkling eye are the invariable accompaniments of health and energy. The same rule applies to the feathers of birds, whose colours are only seen in their purity during perfect health; and a similar phenomenon occurs even among insects, for the bright hues of caterpillars begin to fade as soon as they become inactive preparatory to undergoing their transformation." Whenever there is a difference of colour between the sexes the male is the darker or more strongly marked, and the difference of intensity is most visible during the breeding season, when vitality is at its maximum. It is undoubtedly true that female birds do exercise a choice, but the bulk of the evidence on this point, as collected by Mr. Darwin himself, far from proving that such choice is determined by colour, points in a directly opposite direction. The "most vigorous, defiant, and mettlesome male" seems to be preferred. These attributes may be, and in a majority

* Contributions to the Theory of Natural Selection.

of cases doubtless are, correlated with intensity of colour. But, if so, it is persistency and energy, rather than mere beauty, to which success is due. Three eminent breeders of poultry—Messrs. Hewitt, Tegetmeier, and Brent—informed Mr. Darwin that they "did not believe that the females prefer certain males on account of the beauty of their plumage." Mr. Tegetmeier is convinced that "a game cock, though disfigured by being dubbed and with his hackles trimmed, would be accepted as readily as a male retaining all his natural ornaments." Old hens, and those of a pugnacious disposition, as Mr. Darwin states, quoting Mr. Brent, "dislike strange males, and will not yield until well beaten into compliance"—certainly a curious kind of "Female Selection." Mr. Darwin himself admits that, "as a general rule, colour appears to have little influence upon the pairing of pigeons." The case of the hen canary "who chose for her mate a greenfinch, in preference to either chaffinch or goldfinch," also tells against Mr. Darwin's hypothesis. Nor is the instance of Sir R. Heron's peahens more fortunate. If these birds preferred a pied cock to one normally coloured their conduct was a strange anomaly, because, as Mr. Wallace remarks, "pied birds are just those that are not favoured in a state of Nature, or the breeds of wild animals would become as varied and mottled as our domestic varieties." But if there is no sufficient evidence that female birds in the choice of mates are influenced by the beauty of the opposite sex, the case is still more decided as regards butterflies. Here the males surpass the most splendid male birds at once in brilliance of colouration and in elegance of pattern, whilst the females in a multitude of cases are comparatively plain and obscure. Yet there is no evidence to prove that the female is at all influenced by this beauty, "or even that she has any power of choice." Mr. Darwin himself can find no more satisfactory argument than the following:—"Unless the female prefer one male to another the pairing must be left to mere chance, and this does not appear probable." Yet we observe the males fight and jostle each other in pursuit of a female, who submits herself with indifference to the victor. Mr. Darwin admits that in the case of the silk-moths "the females appear not to evince the least choice in regard to their partners." Would not the same rule be found to hold good with any other Lepidopterous insect, if only observed as extensively? Here, as among birds, "the most vigorous and energetic, the strongest winged, or the most persevering, wins the object of his pursuit." Mr. Wallace adds that "Natural

Selection would here act, as in birds, in perpetuating the strongest and most vigorous males, and, as these would usually be the most highly coloured of their race, the same results would be produced as regards the intensification and variation of colour in the one case as in the other."

But now comes the question, why, if the females are not attracted by the beauty of their mates, do the males make such a striking display of the brilliance of their plumage? Of the fact of such display there can be no doubt whatever. But the main point—the question whether the choice of the females is at all influenced by shades of colour or slight differences in design—is totally unproven. There is no evidence that the females admire, or even notice, the display. "The hen, the turkey, and the pea-fowl go on feeding while the male is displaying his finery." The flutterings and dancings, the erection of tails and crests, are probably a mere result of the exuberant energy with which the male at this season is overcharged.

Mr. Wallace, however, founds his strongest argument on the interference and opposition of Natural and Sexual Selection. He says—"Natural Selection, or the survival of the fittest, acts perpetually, and on an enormous scale. Taking the offspring of each pair of birds as on the average only six annually, one-third of these at most will be preserved, whilst the two-thirds which are least fitted will die. At intervals of a few years, whenever unfavourable conditions occur, five-sixths, nine-tenths, or even a greater proportion of the whole yearly production, are weeded out, leaving only the most perfect and best adapted to survive. Now, unless these survivors are on the whole the most ornamental, this rigid Natural Selection must neutralise and destroy any influence that may be exerted by Female Selection. The utmost that can be claimed for the latter is that a small fraction of the least ornamented do not obtain mates, while a few of the most ornamented may leave more than the average number of offspring. Unless, therefore, there is the strictest correlation between ornament and general perfection, the more brightly coloured or ornamented varieties can obtain no permanent advantage; and if there is (as I maintain) such a correlation, then the sexual selection of colour or ornament, for which there is little or no evidence, becomes needless, because Natural Selection—which is an admitted *vera causa*—will itself produce all the results. In the case of butterflies the argument becomes even stronger, because the fertility is so much greater than in birds, and *the weeding out of the unfit takes place, to a great*

extent, in the egg and larva state. Unless the eggs and larvæ which escaped to produce the next generation were those which would produce the more highly-coloured butterflies, it is difficult to perceive how the slight preponderance of colour sometimes selected by the females should not be wholly neutralised by the extremely rigid selection for other qualities to which the offspring in every stage are exposed."

The above considerations, we submit, fully warrant naturalists, if not in the utter rejection of conscious Sexual Selection, at any rate in placing it in a kind of suspected position, to be condemned except some unexpected piece of evidence should be brought to light in its favour.

But we may venture farther, calling especial attention to the words we have italicised. No one who has made observations with even moderate care, upon any department of the animal kingdom, can doubt the sharpness of the struggle for existence, or can deny that of the eggs deposited by a female butterfly but a very small fraction ever come to maturity. Many no doubt, as Mr. Wallace states, perish as such without ever seeing the light at all. But how is this effected? Every egg of the whole brood is equally and similarly helpless in case of the approach of a devourer or a parasite. None of them can escape by dint of any strength, swiftness, or cunning which it may possess in excess of the rest. Without absolutely saying that no variation can ever be traced among the eggs laid by one mother, we are warranted in declaring that any difference, either in colour, shape, odour, or other properties, which may cause egg *a* to be less easily perceived, or when perceived by an enemy to be more readily rejected, than eggs *b*, *c*, and *d* must be exceedingly trifling, and that the immunity thus gained must be regarded as a mere vanishing quantity. For one that escapes in virtue of such properties ten will owe their survival to what—humanly speaking—must be pronounced mere chance. One egg, without possessing any attribute of superiority or greater fitness, may have been deposited by its mother in a less conspicuous place than the rest. One egg may have perished, not from any comparative imperfection or want of fitness on its part, but because some ovivorous or parasitical insect chanced to pass over the particular leaf to which it was attached. Numbers of other causes might be mentioned—as far as we can judge perfectly accidental—upon which the quickening or the death of an egg may depend. Here, therefore, is no selection, no weeding out, but a destruction of one portion

and a preservation of the rest with as little reference to any properties they possess as if the momentous question had been decided by lot.

From the egg we pass to the larva. Here there are undoubtedly greater individual differences. We can well admit that one caterpillar may have keener senses to perceive the approach of danger, greater agility in escaping, more cunning in concealment, an odour less attractive to enemies than have others, and may thus derive an advantage over them in the struggle for existence, and may thus fairly be pronounced more fitted for the conditions under which it must exist, and better adapted to survive. But here also a vast number of cases must occur in which chance alone can decide. The totally accidental matter of position at some momentous time may be of far greater consequence for the life of a larva than a slight variation in any of the points just enumerated. Thus an ichneumon may oviposit in the bodies of caterpillars *a*, *b*, *c*, &c., whilst caterpillar *x* may escape from the simple fact that the enemy's stock of eggs ready to be deposited was exhausted before she reached it. Or two larvæ upon two different plants may each be threatened by the approach of an ichneumon. But the one invader may become entangled in the web of a spider or be snapped up by a bird, whilst the other meets with no hindrance and effects her purpose. In the pupa state, again, no small portion of the deaths take place; and here we have a reversion almost to the conditions of the egg. Without any reference to attributes of their own, some pupæ may have been discovered by birds, by field-mice, by hedgehogs, and by other of the numerous birds, beasts, or insects who consume such prey with readiness, whilst others by pure accident may have escaped. Whatever effect the first small steps of variation may have had in determining the survival of any given individual, it seems insignificant compared with the effects of chance. The condition of a Lepidopterous insect, from the egg to its emergence as imago, seems very much like that of the inmates of a town under the infliction of a heavy bombardment. It may perish or it may survive, neither alternative being so much determined by its own peculiar attributes as by the position which it occupies at some given moment. With the mature butterfly the case is different. We can well conceive that variations in point of speed, not relatively greater than such as are well known to occur between individuals of one species, may turn the scale for life or for death, and can thus imagine the gradual

elimination of the slower and the preservation of the swifter forms.

From butterflies we pass to birds. In a work containing much with which we are unable to agree,* the author, contending that over-preserving and the extirpation of hawks have not led to the multiplication of weak and sickly grouse, which formerly would have been improved away, and have left more scope for their stronger and healthier fellows, argues that it is not the weaker and slower birds which fall victims to the falcon. The celerity of this destroyer is so tremendously in excess of that of the fleetest grouse that all differences in speed among the latter birds utterly vanish. The strongest-winged and most vigorous moorcock, if once espied in the air by the enemy, has practically no greater chance of escape than a feeble and sickly bird. On the contrary, the boldest and most energetic grouse, who may fairly be assumed to be, as a rule, the healthiest, will fall victims more frequently than their weaker brethren, from the mere fact that they are more active and venturesome, and hence more likely to be on the wing. The effects of the co-existence of falcons and grouse in any country will be, therefore, not the development of a form of the latter better adapted for rapid flight, and ultimately, in the course of many generations, endowed with longer and more pointed wings, but merely a thinning of numbers, which will tell equally upon the strong and the weak, and which in some cases may even give an advantage to the latter.

This argument of Mr. Morant's concerning the influence of the falcon upon the development of the grouse appears to us applicable not merely to this individual instance, but to every case where a bird or a beast has to struggle for existence against enemies greatly its superiors in speed, in strength, or in general resources. Slight increments of swiftness or force, trifling improvements in offensive or defensive arms, would be absolutely thrown away under such circumstances, however valuable they might be as against an enemy but slightly superior to the original form. Hence there are numbers of cases where it must become questionable how, on the principle of Natural Selection, advances in these important directions are to be effected. If variation proceeds not at one uniform rate and by gradations almost imperceptible, but occasionally by more rapid movements, the matter is entirely different. Nor are considerations of

* "Game-Preservers and Bird-Preservers." See Quarterly Journal of Science, vii., 145.

speed and strength isolated in this respect. Something very similar will prevail concerning the advantage which animals gain by their so-called "protective" resemblances, either to other species or to their inanimate surroundings. Let us suppose a creature ill-adapted to escape from its enemies by speed or strength; conspicuous in its form and colouration, and therefore unable to conceal itself; and, lastly, attractive to the smell and taste of rapacious animals, and consequently eagerly sought for by them as food. If, now, one individual of the species varies in colour from the normal standard in a direction slightly verging towards a protective hue, the advantage that it will hence derive in the struggle for existence will be equally trifling, even although a multiplicity of steps such as it has just taken might finally render the modified form scarcely perceptible to its enemies. Or we may suppose that one individual of the persecuted species takes the first step towards the development of a repulsive odour. Here, also, its chances of existence will not be perceptibly increased, though its devourer, if able to reflect so far, may perhaps think that the morsel was not quite so good as usual.

We submit, therefore, that under a multitude of circumstances, if variations of colour or odour, or augmentations of speed, are to give the individual thus modified a greater chance of survival, they must either occur simultaneously in a considerable number of specimens, or they must be advances in the required direction, not slight and scarcely perceptible, but well-marked.

There is another and a different consideration which in our opinion must not be overlooked, as powerfully tending to modify the influence of Natural Selection. It has been argued that individuals favourably modified in any way, but especially as regards strength or swiftness, will stand a much better chance, not merely of escaping their enemies or securing their prey, but also of obtaining mates and leaving offspring. Yet, so far as birds are concerned, this advantage, be it great or small, appears to be neutralised. In Mr. Wallace's work we find the following passage:—"Again, the evidence collected by Mr. Darwin himself proves that each bird finds a mate under any circumstances. He gives a number of cases of one of a pair of birds being shot, and the survivor being always found paired again almost immediately. This is sufficiently explained on the assumption that the destruction of birds by various causes is continually leaving widows and widowers in nearly equal proportions, and thus each one finds a fresh mate, and it

leads to the conclusion that permanently unpaired birds are very scarce; so that, speaking broadly, every bird finds a mate and breeds."

Mr. Morant also remarks that there must exist somewhere "an establishment for unmarried female falcons."

Mr. Wallace very justly argues that this fact must counteract the effects, if any, of Sexual Selection. But it is scarcely less hostile to the action of Natural Selection. Granting that the pairs, as first formed, are composed of the strongest and most vigorous males and of the finest and healthiest females. But after a short time of the non-selective slaughter carried on, if not by man, yet by hawks, ravens, wild cats, weasels, snakes, and other bird-destroyers, the rejected of either sex find themselves mated, and of course become parents, substantially to as great a degree as their more favoured rivals. It may of course be contended that this indiscriminate slaughter falls equally upon the mated and the unmated. We doubt the correctness of this supposition: birds in the various operations connected with nest-building, hatching, and feeding their young, have to expose themselves necessarily more to danger than their bachelor and spinster neighbours. Among the lower animals, as well as among mankind, the pleasures and advantages of married life have, it seems, to be paid for.

Hence, without at all seeking to deny the existence and working of Natural Selection as a force effecting modifications in organic life, which may often extend to the formation of what we call species, we feel bound to admit that its influence is checked and modified in a variety of manners.

In Mr. Wallace's work another interesting question is discussed with results which further strengthen us in the belief that Evolution must have other—and probably more powerful—causes, and has at all events not always been effected by uniform and imperceptible gradations.

We are here reminded that the progressive development of the senses—a point scarcely as yet sufficiently investigated—is one of the most efficient ways in which animals may become modified in harmony with varying circumstances. An individual bird or beast, if possessing sharper sight, more delicate hearing or scent, than the bulk of its fellows, must plainly have a great advantage in the struggle for existence. It will be sooner warned of the approach of an enemy; it will more readily detect the presence of its prey, and will escape a number of subtle dangers to which it might otherwise succumb. Thus most of our readers

will be familiar with the curious case of the pigs in Virginia mentioned by Mr. Darwin. All white pigs, it appears, were destroyed by feeding upon a certain root which took no effect upon black pigs. This remarkable phenomenon is ascribed by Mr. Darwin to a constitutional peculiarity connected with the dark colour, the black animals enjoying a perfect immunity from the effects of a poison which was fatal to all of the white variety. Dr. Ogle, however, gives a different and more probable explanation. He remarks that we have no evidence that the black pigs partook of the root at all. He considers that it possessed an odour or a flavour offensive to their senses, while the white pigs—endowed with less acute and discriminating smell and taste—ate it and perished. This fact is an admirable instance of the importance of acute senses to the preservation and multiplication of a species. Yet at the same time an advance in this respect can rarely be assumed to modify the structure of an animal or cause it to develope into a new species, even though acuteness or dulness of the senses may be respectively correlated with certain colours.

With the acuteness of the senses and its progressive development is naturally connected the history of colour, odour, and flavour in the world. Have the faculties and their objects been evolved in mutual harmony? Especially was colour existent before the colour-sense of animals had become able to recognise it—a process which, as we learn from the existence of colour-blindness, is even yet not complete. Are we to expect further advances as in the faculty, so in what it perceives?

Mr. Wallace considers that "when the sense of sight was first developed in the animal kingdom, we can hardly doubt that what was perceived was light only, and its more or less complete withdrawal. As the sense became perfected, more delicate gradations of light and shade would be perceived. At what grade in animal development the new and more complex sense—which takes cognizance not merely of the quantity of light, but also of its quality—first began to appear we have no means of determining." It was a somewhat prominent tenet of the old Natural History that the phenomena of colour, and indeed of ornamentation, in Nature, existed mainly in reference to man and with a view to his delectation. Mr. Wallace by no means agrees with many leading modern naturalists in the complete rejection of this assumption. He asks—"And even now, with all our recently acquired knowledge of this subject, who shall say that these Old-World views were not intrinsically and

fundamentally sound; and that, although we now know that colour has uses in Nature that they little dreamt of, yet the relation of those colours—or rather of the various rays of light—to our senses and emotions may not be another, and perhaps more important, use which they subserve in the great system of the Universe." Elsewhere he remarks that "the extreme diversities and exquisite beauties of colour seem out of proportion to the causes that are supposed to have produced them, or to the physical needs to which they minister." And again:—"It is hardly conceivable that the material uses of colour to animals and to ourselves required such very distinct and powerfully contrasted sensations; and it is still less conceivable that a sense of delight in colur, *per se*, should have been necessary for our utilisation of it. The emotions excited by colour and by music alike seem to rise above the level of a world constructed on purely utilitarian principles." Yet at the same time he declares, and truly, that he has shown reasons for believing that the presence of colour in some of its infinitely-varied modifications is more probable than its absence, and that variation of colour is an almost necessary concomitant of variation in structure, development, and growth. On the colour-sense in animals he remarks "that the higher vertebrates, and even some insects, distinguish what are to us diversities of colour, but this by no means proves that their sensations of colour bear any resemblance to our own. An insect's capacity to distinguish red from blue or yellow may be (and probably is) due to perceptions of a totally distinct nature, and quite unaccompanied by any of that sense of enjoyment, or even of radical distinctness, which pure colours excite in us. Mammalia and birds, whose structure and emotions are so similar to our own, do probably receive somewhat similar impressions of colour, but we have no evidence to show that they experience pleasurable emotions from colour itself when not associated with the satisfaction of their wants or the gratification of their passions."

There is here, it appears to us, some little assumption. We have certainly no evidence that birds and beasts experience pleasurable emotions from colour alone. But what evidence have we to the contrary? The capacity of an insect to distinguish colours *may* be accompanied by any of that sense of enjoyment which pure colours excite in us. But why should we pronounce this probable? Still more, why should its power to *distinguish* colours be unaccompanied by a sense of radical *distinctness?* Quite admitting that the

sight-organs of insects may differ from our own no less in mode of action than they do in structure, we should be prepared to expect that their perceptions may in nicety and accuracy surpass our own. Mr. Wallace himself, in his "Contributions to the Theory of Natural Selection," says "their [insect's] sight may far exceed ours both in *delicacy* and in range." In the present work, also, Mr. Wallace treats of colour as affording a means of mutual recognition, of especial value to insects, though he adds that "in birds such marked differences of colour are not required, owing to their higher organisation and *more perfect* senses." Now we have certainly no facts to prove that the sense of smell in birds ever attains anything like the delicacy and accuracy which are evinced in the case of certain insects—those, for instance, who are caught by the stratagem of "sembling."*

The brilliant and striking colouration of many berries Mr. Wallace considers may subserve the dissemination of the species. Birds attracted by the colour swallow the berry, and void the seeds in localities where they may take root. The same brilliant hues occur also, however, in larger fruits, where the seeds are never swallowed. Both birds and insects show that they are perfectly able to distinguish a ripe cherry, plum, or peach from one that is still green, and generally confine their attentions to the more highly coloured sunny side; but the stone is left hanging on its stalk. Consequently the possession of striking colours by the fruit, and the recognition of such colours by birds, wasps, butterflies, &c., does not aid in the multiplication of the tree.

Mr. Darwin and Mr. Wallace both seem to agree that the highly-coloured spots on the wings of butterflies, being generally placed remote from any vital organ, may have a protective effect, causing birds to strike at these parts rather than at the head or body. If, however, we carefully consider the flight of a butterfly, we shall be inclined to doubt whether a blow aimed at the tips of the wings might not be quite as likely to fall upon the body.

Public attention has lately been drawn to a point in the history of colour-perception in our own species, which at first sight seems to have an important bearing upon the antiquity of man and the rate of his intellectual development, as well as to throw a useful side-light upon sexual selection, upon mimetism, and other phenomena among the lower animals. It is well known that a large proportion of

* Quarterly Journal of Science, vol. viii., p. 304 (July, 1878).

living men and women in modern civilised nations (according to some authorities about 5 or 6 per cent), whilst perfectly able to distinguish by the eye the outline and texture of any object placed before them, its apparent distance, and its degree of illumination, fail more or less completely to recognise colours. To such persons scarlet and green are respectively undistinguishable, and are both liable to be confounded with grey. In other cases the eye perceives no difference between blue and yellow, and in some extreme instances the solar spectrum appears merely as a band lighter in some portions and darker in others, and all objects are viewed as if by a monochromatic light.

But imperfect as is the human colour-sense at the present day, there is, in the opinion of some, evidence that it has distinctly advanced within the brief span known as "historical time." Philologists have been struck with the fact that in the most ancient writings extant, such as the Bible, the Vedas, the Zendavesta, and the poems of Homer, no definite nomenclature for colours can be traced.

The phenomena of colour seem to have attracted less attention at the times when the above writings were produced than at the present day. One and the same term is applied to blue, to green, and to black objects. Iron is called by Homer "violet-coloured." In the autumn of 1877 an article by Mr. Gladstone on the colour-sense, as exhibited in the poems of Homer, appeared in the "Nineteenth Century," and has since been reproduced in the "Revue Internationale des Sciences." The writer there formally undertakes to show that the few colour-terms used by Homer are applied to objects so different among themselves "that they cannot denote colours as we perceive and differentiate them, but seem more applicable to different intensities of light and shade. Thus, to give one example, the word *porphureos* (ordinarily rendered purple) is applied to clothing, to the rainbow, to blood, to a cloud, to the sea, and to death, and no one meaning will suit all these applications except comparative darkness." In other cases the same object has varying colour-terms applied to it, the meaning of these being indicated merely by a reference to other objects fluctuating in themselves, so that the difficulty of determining what hue the writer meant in any particular case is insuperable. "Mr. Gladstone concludes that archaic man had a positive perception only of degrees of light and darkness, and that in Homer's time he had advanced to the discrimination of red and yellow, but no further, the green of grass and foliage and the blue of the sky being never once referred to."

But the very same want of reference to definite colours and the same poverty of colour-terms may be traced in literature very much later than the epoch of Homer. Thus Latin authors who flourished as late as the first century of the Christian era apply the word *cæruleus* to sky-blue, to steel-blue, to the colour of the human eyes, to the olive tree, and to dark grey and black objects; *viridis*, commonly rendered green, is used by Virgil for the colour of the human face when turning pale, and by Pliny for the hue of the clear heavens; *purpureus* is applied to the poppy, to the rainbow, to the violet, the rose, the willow, the human hair, the sea, and to the face when blushing. The colour of the sky is never mentioned in the Koran, and, according to Geiger, is first clearly alluded to in an Arabic work of the ninth century.

Now, that the vision of man, and indeed of all animals, was at one time monochromatic, and has gradually reached its present stage of development by a passage through some of the phases of what we now call colour-blindness,—which must be regarded as a reversion to an earlier condition,—we feel no difficulty in admitting. But that the human colour-sense should remain in a condition so rudimentary down to the days of Homer, and even of Aristotle, Pliny, and Vitruvius, and should then advance by "leaps and bounds" to its present condition, is an assumption difficult to realise, and scarcely compatible with our modern evidence concerning the antiquity of our race.

Mr. Wallace, with his usual acute insight, detects an error in the conclusion to which Mr. Gladstone has been led. He remarks:—"These curious facts, however, cannot be held to prove so recent an origin for colour-sensations as they would at first sight appear to do, because we have seen that both flowers and fruit have become diversely coloured in adaptation to the visual powers of insects, birds, and mammals. Red being a very common colour of ripe fruits which attract birds to devour them, and thus distribute their seeds, we may be sure that the contrast of red and green is to them very well marked. It is indeed just possible that birds may have a more advanced development of the colour-sense than mammals, because the teeth of the latter commonly grind up and destroy the seeds of the larger fruits and nuts which they devour, and which are not usually coloured; but the irritating effect of bright colours on some of them does not support this view. It seems most probable, therefore, that man's *perception* of colour in the time of Homer was little, if any, inferior to what it is now, but

that, owing to a variety of causes, no precise *nomenclature* of colours had become established. One of these causes probably was that the colours of the objects of most importance, and those which were most frequently mentioned in songs and poems, were uncertain and subject to variation. Blood was light or dark red, or when dry blackish; iron was grey or dark, or rusty; bronze was shining or dull; foliage was of all shades of yellow, green, or brown; and horses or cattle had no one distinctive colour. Other objects—as the sea, the sky, and wine—changed in tint according to the light, the time of day, and the mode of viewing them; and thus colour, indicated at first by reference to certain coloured objects, had no fixity. Things which had more definite and purer colours—as certain species of flowers, birds, and insects—were probably too insignificant or too much despised to serve as colour-terms; and even these often vary, either in the same or in allied species, in a manner which would render their use unsuitable."

Mr. Wallace might here have added that the attention of the Oriental and Mediterranean nations was always turned towards man rather than to external nature. Hence their comparative indifference to beautiful scenery, their neglect of landscape painting, their failure in physical science, and their contempt for the industrial arts—so remarkable if we consider their degree of civilisation and the high intellectual development to which some of them had attained. That such nations should have no very precise nomenclature for colours—a nomenclature chiefly required in the pursuit of Natural Science and in certain manufactures—affords no proof that their colour-sense was not as perfect as our own. Hence it cannot be contended that the facts signalised by L. Geiger and by Mr. Gladstone enable us to draw any trustworthy inference as to the antiquity of the human race.

This brings us in contact with the subject which we are only just learning to discuss with scientific calmness and candour. The day is scarcely over since the dreams of Archbishop Usher and his coadjutors were supposed to be founded upon the direct testimony of Revelation. The notion that the world was "created in autumn 4008 years before the vulgar Christian era," and that our species had consequently not existed for quite 6000 years, was accepted as a main point of faith. Facts and arguments which pointed to a longer date raised gratuitous alarm among Christians, and exultation no less gratuitous among atheists. These mists and clouds are now clearing away, and thinkers

of unimpeachable orthodoxy now admit that there are no theological grounds for a denial either of the antiquity of man or of the doctrine of Evolution, and that the Church may watch the contest between the Old and the New Schools of Biology as calmly as she did that between the Phlogistian and the Lavoisierian Schools of Chemistry. But Mr. Wallace puts in a word of caution which cannot be deemed useless. He reminds us that the hypothesis now dominant in scientific circles, that man has been gradually developed from some lower animal form, and that he has existed upon the earth from the Miocene epoch, possibly even from the Eocene, is not unbeset with difficulties. In the interests of Science these should receive full and fair consideration, and not be ignored, as were till recently the facts incompatible with the chronology of Usher. It is recognised as a curious circumstance that, notwithstanding the care with which pre-historical human remains have been sought for in all civilised countries,—notwithstanding the incidental facilities for research afforded by railway excavations, mines, and other engineering operations,—little if any light has recently been thrown upon the time or the mode of man's origin. "Amid the countless relics of a former world that have been brought to light, no evidence of any one of the links that must have connected man with the lower animals has yet appeared." Professor Mivart, in his well-known work "Man and Apes," has shown, by a most careful structural analysis, that man is related not exclusively and specially to any one of the anthropoid apes now existing, but almost equally to the orang, the chimpanzee, the gorilla, and the gibbon. Hence, on the evolutionist hypothesis, he is descended not from any one of these, but from an extinct and as yet unknown form which must have branched off at an exceedingly early date from the common stock. "As far back as the Miocene deposits of Europe we find the remains of apes allied to these various forms, so that in all probability the special line of variation which led up to man branched off at a still earlier period. And these early forms, being the initiation of a far higher type, and having to develope by natural selection into so specialised and altogether distinct a creature as man, must have risen at a very early period into the position of a dominant race, and spread in dense waves of population over all suitable portions of the great continent—for this, on Mr. Darwin's hypothesis, is essential to developmental progress through the agency of natural selection."

Such being the case, it is asked why we find no relics of

earlier forms of man in company with those of other animals which were, *ex hypothesi*, less abundant? We reply that not one-hundredth part of what is now dry land has hitherto been satisfactorily explored. Possibly the extinct anthropoids may have mainly inhabited some of the regions which existed where now there roll wide, though shallow, seas. Living, as we might expect, among low-land tropical forests, their bodies, when dead, would be fully exposed to all the destructive agencies of Nature. Perhaps their habits were specially unfavourable to the preservation and fossilisation of their remains. Perhaps cannibalism was widely prevalent in those days. The order Primates is hitherto but sparingly represented among the fossil Mammalia. Nay, leaving the geological ages out of the question, and coming down the stream of time to within historical days, let us take some country which we know to have been densely peopled from four thousand to three thousand years ago, and ask how many human remains of such dates could be there discovered? We naturally except Egypt, and any other country where it was customary to embalm the dead. Is there some cause why the skeletons of the anthropoids and of man are more perishable than those of the lower forms of vertebrate life? Some writers have suggested that as the Quadrumana are now almost exclusively tropical, and the anthropoid species even equatorial, we should look for the earliest ancestors of man in such regions as the Malay Islands or Western Africa. To this Mr. Wallace replies that existing anthropoid apes are confined to equatorial regions because there only can a perennial supply of fruits suitable for their nourishment be found. But as in the Miocene epoch Southern Europe possessed an almost tropical climate, this restriction as to locality might then not have existed. Still experience shows us that a species is not necessarily found wherever conditions suitable for its existence are present.

We must, however, admit that if further geological exploration fails to place in our hands a greater number of human remains from the pre-historic ages, and especially anthropoid forms lower than the existing races of man, though higher than any existing apes, the views now dominant in scientific circles concerning the origin and early history of our race will stand in need of a careful revision. We shall apparently have to admit that man, however ancient, can scarcely have been formed by that slow and uniform process of development which must result from the operation of Natural Selection. It will be, as Mr. Wallace

declares, "at least a presumption that he came into existence at a much later date and by a much more rapid process of development. In that case it will be a fair argument that just as he is in his mental and moral nature, his capacities and aspirations, so infinitely raised above the brutes, so his origin is due in part to distinct and higher agencies than such as have affected their development."

But is it necessary that the process of Evolution, by whatsoever agencies effected, must always have maintained a uniform degree of speed? We have no desire to recur to "catastrophism," geological or biological, or to represent unknown and immeasurable forces as being arbitrarily introduced into action and again as arbitrarily withdrawn. But we find in phenomena governed by forces strictly natural, and even measurable, changes occurring more rapidly at certain stages than at others. To take a simple and familiar instance, the progressive increase of the length of the day in spring and its corresponding decrease in autumn is much more rapid at the equinox than at any other time. Or, turning to a region much more closely connected with the subject in hand, if we observe the development of an individual man—or indeed of any other animal—from birth to maturity, we do not find equal amounts of progress effected in equal successive portions of time. We know that in the life of a youth there is a period when, in stature and in the development of his mental and bodily powers, he appears almost at a standstill for two or three years, this lull being followed by a period of intensified growth, in which he shoots up at once into manhood. Is it not at least possible that a similar want of uniformity may be traceable in the evolution of species? Prof. Leconte argues that every organism will oppose a certain amount of resistance to agencies calculated to effect a change. This resistance being once overcome, change will be for a time rapid, until a state of approximate equilibrium is again reached. Hence we may expect that at certain points where a great change has taken place certain "links"—the intermediate forms—will be missing. Their career is likely to be exceedingly short, not running to many generations, and for the same reason the number of individuals must be limited. Hence the probability of the fossil remains of such "links" being preserved for our inspection is infinitesimal indeed. When, on the other hand, the equilibrium is re-established, species exist with little change for centuries, possibly for thousands of years; they spread over every accessible land suitable to their requirements, and increase in numbers as far as the

supply of food and the other conditions of existence will allow. The probability is, then, that of the multitudes of individuals who successively flourish some will die under circumstances favourable to the fossilisation of their remains.

The differences of opinion we have been considering on the mode in which Evolution is effected, its main causes, and the laws of its action, are not surprising in view of the extent, the complexity, and the difficulty of the subject. Mr. Darwin has not so much solved the great problem of organic life as shown the way in which its successful study and its ultimate solution are possible. But whilst the greatest naturalists of the day are eagerly and patiently devoting themselves to this task, there are others who still feel free to introduce into the question extraneous difficulties, and to appeal to the passions and prejudices of an unscientific public.

Whilst waiting for an unpunctual train, at Dartford Station, our eye was caught by Mr. Morris's pamphlet. We read it through with equal feelings of surprise and regret. It is a work which might have been pardoned if it had appeared ten years before its actual date (1875), and if it had been from the pen of some journalist, novelist, barrister, &c., who could scarcely distinguish a humming-bird from a Sphinx-moth; but the Rev. F. O. Morris is himself a naturalist of merit, and, had he been so minded, might surely have criticised Mr. Darwin's theories, if unfavorably, still in a manner more useful to Science and more creditable to himself. As it is he sins equally against good taste, logic, and facts. Here is a specimen taken at random :—"I believe that such persons, in former times, as Sir Isaac Newton, Herschell, Lord Bacon, Dr. Johnson, Milton, Locke, Sir Matthew Hale, &c., who were believers in the Bible, were far behind me in intellect and knowledge. I believe, in like manner, that others in the present time, who are believers also as they were, such as Sir Roundell Palmer, Lord Hatherley, Lord Shaftesbury, Faraday, Sir David Brewster, &c., and others who like them have taken the highest honours in the Universities, and distinguished themselves in the highest departments of art, science, and politics, are quite beneath me in mind and attainments, for if I am right —as I must be, and therefore am—they of course must be wrong."*

* It might be asked in what University Faraday graduated, till the day when he conferred rather than received honour by accepting degrees? We might also inquire in what "highest departments of art" Sir Roundell Palmer Lord Hatherley, or Lord Shaftesbury has distinguished himself?

What is all this but the old stale sneer which for ages has been levelled against every inventor and discoverer, who is taunted with setting himself up to be wiser than all the eminent men of the past! But Mr. Morris "double-banks" the fallacy. None of the distinguished men he mentions are biologists at all, and therefore, as far as the subject is concerned, they are all immeasurably inferior in knowledge and attainments to Mr. Darwin. Further, there is the gratuitous assumption that Mr. Darwin, as an Evolutionist, must necessarily reject the Bible. We know many Evolutionists who unhesitatingly accept the Bible as a moral and spiritual revelation, though they do not manipulate it into a geological text-book, or believe in the human traditions—chronological especially—which have sprung up around it. But Mr. Morris not merely accuses Mr. Darwin of Infidelity, but, if we do not misunderstand him, of a formal and conscious Infidel propagandism. "I have done all I could to make others as wretched as I am myself." "I do my little best or worst to shake their faith," &c. Need we put on record our solemn conviction that the aims of Mr. Darwin, Mr. Wallace, and of the majority of the naturalists of the new school, have been purely biological, and that to furnish arguments to the Infidel was no part of their plans? Need we remind Mr. Morris that charges closely analogous to those which he insinuates against Mr. Darwin were brought against Sir Isaac Newton, and with quite as much plausibility? Need we repeat that he who thinks to decide a scientific controversy by such foul play forfeits, *ipso facto*, all claim to the treatment of a gentleman and a scholar, and should at once be handed over to a very different court than that of the reviewer?

As a "supplement" to his curious collection of imputations and travesties, Mr. Morris gives certain extracts from the daily papers! We should have hoped that every man of science in England, or rather in Europe, must be fully aware of the gross blunders made by political and literary journals whenever they condescend to discuss a scientific question. One daily paper not long ago informed the world that "all gases explode far below redness, leaving nothing but a few particles of dust." A journal that displayed such ignorance on a question of history, of law, or of theology, would be well-nigh laughed out of existence. But an error in physics, or chemistry, or biology is detected by few, and therefore the proprietors of political papers do not think it worth their trouble to refer the criticism of a scientific treatise or a presidential address before the British Associa-

tion to an expert. If Mr. Morris finds it necessary to call in the aid of "Punch," the "John Bull," or the "Globe," he only betrays his own "plentiful lack" of sound argument. But there is yet a final court of appeal: the authority is invoked of one who, we suppose, is no less distinguished by his candour, his courtesy, and his strict regard for truth, than by his vaunted "thinness of skin," his freedom from egotism, and the typographical eccentricities of his works, where italics and small capitals cover a multitude of sins. The pamphlet is, it seems, dedicated to "The Right Honourable the Common Sense of the People of England." We have more than once been compelled to point out that "common sense" is the name under which many worship their own ignorance. We were partly in the wrong: it is the name they invoke when they seek to utilise the ignorance of others.

III. THE "WOMAN'S-RIGHTS'" QUESTION CONSIDERED FROM A BIOLOGICAL POINT OF VIEW.

SINCE Natural History was remodelled by Mr. Darwin it has been found capable of throwing valuable lights, previously little anticipated, upon topics quite unconnected with the origin and attributes of zoological or botanical species. Of this solidarity of the sciences—one supplying another with methods of inquiry—a striking instance is afforded by a recent work,* in which the doctrine of Natural Selection is successfully utilised in the study of certain political subjects. That futher applications more or less analogous are still possible will scarcely be doubted. There is in particular one question now agitating human society which seems particularly to require such treatment. Everyone knows that of late years a movement has sprung up to secure for women, as contra-distinguished from men, certain rights, liberties, and powers of which it is contended they have been arbitrarily and wrongfully deprived. To

* Physics and Politics, by WALTER BAGEHOT.

define this movement, and to formulate distinctly the demands of its supporters, is a scarcely possible task. Innovators and agitators of all kinds enjoy the advantage that they cannot be tied down to any fixed set of propositions by which and by whose logical consequences they are prepared to stand or fall. On the contrary, if one ground is found untenable another is instantly taken up; what satisfies one champion of the cause is rejected by another, and what to-day is accepted as final—as in the case of the anti-vivisection movement—is to-morrow proclaimed a mere instalment, and made the basis of fresh demands.

Perhaps we may best describe the movement as an attempt to obliterate all—save the purely structural—distinctions between man and woman, and to establish between them a complete identity of duties and functions in place of that separation which has more or less hitherto always existed. That certain speakers and writers, not content with mere identification, go on to inversion, and would assign to men the particular tasks now allotted to women, though a significant fact, need not detain our attention.

It is of no use laughing at this agitation as the outcome of a mere "crotchet." In certain states of the moral atmosphere crotchets spread just as do epidemics—which they closely resemble—in certain conditions of the physical atmosphere and other surroundings of man. Who would attempt to deal with the cholera or the small-pox by ridicule, how pungent and incisive soever?

We purpose therefore to examine this movement in the light of the principles of Natural Selection, of Differentiation, and Specialisation, and to enquire whether the relations of the sexes in the human species and the distribution of their respective functions are or are not in general harmony with what is observed in that portion of the Animal Kingdom which lies nearest to man—to wit, in the Mammalia. With the origin and history of the agitation, with the hopes and motives of its supporters, and with the ethical, sentimental, economical, and political arguments used on either side we have no direct concern.

Even a very superficial and popular survey of the class Mammalia will satisfy us that the structural differences between the males and the females of each species are by no means confined to the reproductive organs. The male ruminant, whale, bat, elephant, rodent, carnivore, or ape, is on the average a larger and heavier animal than his mate. The tiger, for instance, exceeds the tigress in size by a proportion of from 10 to 20 per cent. In few, if any, species

is the superior stature of the male more striking than in the one which approaches man most nearly in its physical development—the gorilla.

But the mere difference of size is not all; the female is scarcely in any normal case a mere miniature copy of the male. Her proportions differ; the head and the thorax are relatively smaller, the pelvis broader, the bones slighter, and the muscles less powerful. The male in many cases possesses offensive weapons which in the female are wanting. In illustration we need only refer to the tusks of the elephant and the boar, and the horns of many species of deer. On the contrary, there is no instance of a female mammal possessing any weapon which is not also found, to at least an equal degree, in the male.

Further, the superior size of the head in the male, is not merely due to the more massive osseous growth needful for the support of tusks, horns, &c., but to a proportionately larger development of brain. Thus, according to the recent investigations of M. le Bon* "taking the mean weight of seventeen brains of human males, of 154 to 164 centimetres in height, and comparing them with the brains of seventeen women of the same stature, we find between the two a difference of 172 grms. (nearly 6 ounces) in favour of the male."

Summing up these facts, commonplace but not the less important, we see that in the whole mammalian class, man included, the males are distinguished from the females, not merely by larger size, but by superior cerebral and thoracic development, and by the more general possession of offensive weapons. On the other hand, trite as the remark may seem, the organs for the nutrition of the young are exclusively confined to the female. Are we to suppose that these sexual differences are devoid of meaning, merely accidental, or artificial in their origin?

We must next inquire to what functional distinctions these structural differences correspond, and what is their signification? It is generally admitted that among animals of one and the same species the larger will be found to be the stronger, and generally speaking physically the superior. Exceptions doubtless occur, but if we were to take one hundred men in normal health whose "fighting weight" ranged from 11 to 12 stone each, and compare them with another hundred averaging a stone less, we should find the former set able to lift greater weights, strike harder blows,

* Comptes Rendus, lxxxvii., No. 2, p. 80.

and in every way excel the second lot in athletic performances.

Again, it is found that the size of the chest, and consequent volume of the lungs, affords a very good standard by which the general vigour, the vital energy of either man or beast may be gauged. The more a man, free from corpulence, measures round the chest, the better are his stamina, and the greater his power to support fatigue and hardships. Of this fact the military and the sporting world are perfectly aware, and never fail to take it into account in estimating the eligibility of a recruit or the probable performances of an athlete.

Having seen, then, that male animals are not merely actually larger than their respective females, but surpass them proportionally in the size of the thorax, we naturally expect the former to be decidedly the stronger, gifted with a more intense and exuberant vitality. Nor are our expectations disappointed. The bodily strength of a cow is trifling indeed compared with that of a bull of the same breed. In races a filly is very frequently—merely as such—allowed to carry less weight than a horse. A lady gorilla would be in evil case indeed if her husband did not treat her with a gentleness and kindness which many of our own species would do well to imitate. And as to mankind—Is not, perhaps, the most legitimate source of the very movement we are criticising an attempt to secure women against the superior strength of men? Yet at a meeting at Manchester a male agitator actually sought to deny the superior physical power of man, because it would be easy to find a fish-wife stronger than a cotton-weaver. The argument being intensely illogical was frantically applauded.

Persons are not, however, wanting, who—whilst admitting the general inferiority of women to men in physical strength—contend that this weakness is the result of continued and systematic repression. Woman, they say, has been forcibly debarred from invigorating pursuits, and comparative feebleness is the natural result. We would ask such advocates whether this systematic repression has been also carried out among the lower mammals, and, if not, what is the origin of the weakness of the female sex in their case, which is at least as well marked as among mankind? Has the "subjugation" of woman had its parallel in the "subjugation" of the cow, the mare, the ewe, the lioness?

That the women of the middle class in all civilised countries, and of the higher in some, would be much healthier and stronger if they took more exercise in the open air and

swallowed less tea, we admit. But in that case we contend that their increased vigour would descend not to their daughters exclusively or specially, but to all their children.

Further, in some countries and among certain classes, a great amount of physical labour falls to the lot of the women, without their being thereby rendered equal in strength to the men. Among the North-American aborigines the squaw has the monopoly of hard work, whilst her husband—save when on the chase or on the war-path—indulges in idleness. Yet he runs no risk on that account of being surpassed in strength by his wife, and ultimately finding himself in consequence "subjugated."

No less is the superior cerebral development of the male sex in the human species, to which we have already referred as an indisputable fact, devoid of functional importance. It has, indeed, been contended that the difference in weight between the brain of the two sexes is a mere "survival" from some lower state of civilisation, or of existence which we may expect to see ultimately disappear. Such hopes, if they anywhere exist, must be abandoned in view of the results of M. le Bon, already quoted. This biologist finds that "the difference between the respective weight of the brain in man and woman constantly goes on increasing as we rise in the scale of civilisation, so that as regards the mass of the brain, and consequently in intelligence, woman becomes more and more differentiated from man. The difference which exists between the mean of the crania of contemporary Parisian men and that of contemporary Parisian women is almost double of the difference which existed in Ancient Egypt."

Taking hold of this simple fact, that the brain in the male is not merely larger, but increasingly larger, than in the female, we need not long search for its meaning. As the same writer to whom we have referred declares, "On examining series of crania sufficiently numerous we find that in the human species the largest brains belong to the races highest endowed intellectually, and in each race to its most intelligent members. Just, therefore, as higher civilisation is heralded, or at least evidenced, by increasing bulk of brain; just as the most intelligent and the dominant races surpass their rivals in cranial capacity; and just as in those races the leaders, whether in the sphere of thought or of action, are eminently large-brained,—so we must naturally expect that man, surpassing woman in volume of brain, must surpass her in at least a proportionate degree in intellectual power. We are sorry to be compelled here to own

that while we know that in most, if not all, mammalian species the brain of the male exceeds in size that of the female, we have no observations as to any corresponding difference in mental power. That such difference, on careful examination, will be found to exist is highly probable; but we must likewise expect that it will be found less distinctly marked the lower the rank of the species.

To return: the intellectual superiority thus claimed for the male sex, in virtue of a higher cerebral development, is fully manifested in the history of the various arts and sciences. In every department the first, the leading, minds have belonged to the male sex. Homer, Shakspeare, Phidias, Beethoven, no less than Newton, Liebig, and Darwin, are men.

In reply to this historical confirmation of what biology foretells, the advocates of the movement adduce three arguments, all, in our opinion, singularly inconclusive.

Admitting the superiority of the male brain in bulk and weight to that of the female, they maintain the existence of a qualitative difference which renders the two incommensurable. This hypothesis, however, is a pure assumption. We should have an equal right to maintain that the brains of different races of men, especially as existing in ages widely remote from each other, were incapable of mutual comparison. Or, in the same spirit, it might even be urged that the smaller size of the muscles in woman was no proof of any inferiority in physical strength.

Secondly, it is contended by those who seek to identify the duties, functions, and spheres of action of the two sexes, that many women have distinguished themselves in the arts and sciences. Admitting to the full this fact, we can only place it on a level with the kindred phenomenon that not a few women have, in disguise, entered the army or navy, and have acquitted themselves as creditably as their male comrades; or that others have worked long and undetected as excavators, in the construction of railways, &c. The *savante*,—the woman of science,—like the female athlete, is simply an anomaly, an exceptional being, holding a position more or less intermediate between the two sexes. In the one case the brain, as in the other the muscular system, has undergone an abnormal development. That such cases should occur need no more surprise us than does the converse phenomenon, the existence of womanish man. We meet with subjects, otherwise of the male sex, in whom the beard is scanty or wanting, the limbs slight and rounded, the voice high, the chest narrow, and the pelvis broad, or

who, if they do not structurally approximate to the female sex, betray a preference for feminine occupations, which wins for them such epithets as "molly-cots," "cot-queans," &c. At the risk of somewhat anticipating ourselves we cannot suppress the remark that no one demands especial laws and institutions for the benefit of such womanish men, or proposes their exemption from the customary duties of the male sex, how burdensome soever these may be felt.

The third and last plea put forward to explain, if possible, the cerebral inferiority of woman and her concomitant intellectual inferiority, is an adaptation of the one already proposed to account for her smaller physical strength. It is gravely asserted that mental activity in art or science has been systematically repressed among women, and that in consequence their cerebral development has been injuriously interfered with. To this contention it would be a sufficient reply were we to simply point to the fact already mentioned, that the relative inferiority in the size of the brain of women, instead of diminishing as their social status has improved, has, on the contrary, been increasing. We may hence fairly argue that it exists not in virtue of any artificial interference, but of a law of Nature. We can, however, adduce other considerations. In the pursuit of the fine arts, woman, instead of being checked and hindered, whether by law or by social conventions, has been encouraged. An acquaintance with music has been literally forced upon every girl of the upper and middle classes. Yet, leaving composers out of the question, how many of the million female performers on the pianoforte, now to be be found in Europe and America, can take rank with Liszt and Thalberg? In the highest development of literature, poetry, sex has been no obstacle to the recognition of merit. Yet neither Sappho in the past nor Mrs. Hemans and Mrs. Browning in our own day can be placed even in the same class with the leading poets of Greece, England, and Germany.

Women have certainly till of late met with few direct facilities for the pursuit of science. But, in England at least, neither have men. Our great scientific discoverers, until quite recent days, have been substantially self-taught, and even if in their youth they enjoyed a university education their subsequent researches, though *post hoc*, have assuredly not been *propter hoc*. Scientific books and apparatus have been as accessible to one sex as to the other; and these have generally been the only opportunities that our discoverers have had at their command. How to use such appliances they had to discover for themselves. We deny, therefore,

that the exclusion of young women from universities, *in which modern sciences were not taught,* can have hindered them from entering upon a scientific career. Equally do we deny that public opinion forbade for them study and research. Had Miss Herschell been a man her astronomical discoveries could not have been more highly or more deservedly appreciated. Not a dog barked at her for preferring determining the orbits of comets to ordinary feminine avocations. In like manner, if any woman had possessed the necessary faculties and turn of mind, there was nothing in the way of public prejudices or established customs to prevent her from having anticipated Dalton in discovering the laws of definite chemical combination. Nor if thus discovered would the "atomic theory" have met with a less favourable reception. We then entirely deny the existence of any supposed conspiracy to repress scientific talent in the female sex, and we hold that the three arguments adduced to explain its comparative rarity among women to be utterly inconclusive.

A further distinction between the sexes, common to mankind and to all the mammalian class, must be sought in the moral faculties. Take what species we like we find the males bolder, more pugnacious and quarrelsome, more adventurous and restless, and less tractable and docile. The females, on the other hand, save in protection of their young from real or supposed danger, are mild, gentle, and inoffensive. Of this no more indisputable instance could be found than the case of domestic cattle, the cow—with the exception of certain "strong-minded" individuals—being perfectly harmless, whilst the bull, when above four years old, is one of the most dangerous animals known, attacking and killing human beings, not for food, like the lion or the tiger, but out of pure "superfluity of naughtiness." Very similar is the distinction between the character of the sexes among the Quadrumana. No animal is more wantonly and gratuitously mischievous than an adult male baboon, and we are unable to find an instance of one having been tamed so far that he could be allowed his liberty. The females, on the other hand, are capable of domestication. Were there any necessity to multiply instances a fair-sized volume might be filled with accounts of the intractability of male Mammalia of different species, as contrasted with the mildness and docility of their females, whilst in no animal is the case reversed.

That the sexual distinction of character in our own species is precisely analogous in its nature will, we trust, be admitted without argument.

We find, therefore, summing up the foregoing facts, that throughout the mammalian community the males are larger and heavier than the females, whom they moreover especially exceed in thoracic and cerebral development; that they are consequently stronger, more intensely animated, and in disposition bolder and fiercer. The very same differences are found in average men as compared with average women, with the additional peculiarity that here the superior size of brain expresses itself in higher intellectual power.

It would be ridiculous to suppose that all these diversities, structural and functional, are objectless, and do not imply a corresponding diversity of duties. This accordingly we find to be the case:—The male, at least in all species which form unions of any degree of permanence,—whether monogamous or polygamous,—defends and protects the female and her young ones. Thus if a herd of elephants is menaced the most powerful tuskers take their station on the side where danger appears, whilst the females and the young are placed as far as possible out of harm's way. If bisons are attacked by wolves the bulls form a circle enclosing the cows and calves. A similar order is adopted by wild horses. A gorilla will encounter any danger in defence of his mate, and even among baboons the old males will face an approaching enemy while the weaker members of the troop make good their escape. A lion has been seen in the same manner covering the retreat of his lioness and her cubs.

Other examples might be given were it at all needful, but those already stated are surely sufficient to establish the principle. Among herbivorous and omnivorous species, where food is plentiful, there is no occasion for the male to take upon him the duties of provider, but among the Carnivora he frequently supports as well as defends his family. The lion is in this respect a well-known instance.

We find, therefore, that throughout the class Mammalia the respective tasks of the two sexes are precisely such as we find in our own species; the male is the defender and provider, wherever such defence and provision are necessary; the female is the nurse. The man who brings home to his wife his weekly earnings, his professional fees, or his share of the profits of a business, merely repeats on a higher scale the action of the lion who carries a deer or an antelope to his den. Each sex fulfils the tasks for which it is specially adapted by Nature, and anything like "subjugation" is utterly out of the question. Were the duties of the two sexes confounded together, or, still more, were they inverted,—the female, for instance, going forth to face danger or to

hunt for prey, while the male was left to nurse the young,—the position of the species in the great and constant struggle for existence would be very decidedly altered for the worse. We must conclude, therefore, that the attempt to alter the present relations of the sexes is not a rebellion against some arbitrary law instituted by a despot or a majority,—not an attempt to break the yoke of a mere convention; it is a struggle against Nature; a war undertaken to reverse the very conditions under which not man alone, but all mammalian species have reached their present development. Sentimental speakers and writers have commented on the well-known fact that even a very young boy will, to his utmost ability, defend his sister or female playmate, and have expressed a hope that this habit—the result of early training—would wear out, the female no longer needing and the male no longer offering protection. Alas! is the very same habit in the ape, the lion, or the bison the result of a mistaken training, or of an Old-World convention, to be laid aside in these enlightened days? What would be the position of a family of young lions if both their parents went forth to hunt? Yet very similar will be that of children if their mother, as well as their father, goes out to the daily toils of a profession, leaving them perhaps to themselves,—perhaps to the care of ignorant and unprincipled hirelings. The results of mothers withdrawn from domestic duties, and spending their days in industrial pursuits, have been sufficiently exemplified in our manufacturing towns. Here, in the very highest interests of the race, it has been found necessary to check and limit female labour, which ought never to have been introduced. Had this precaution been taken a man would have been able to earn as much as he and his wife jointly have been able to realise under the factory system. But what reason have we to expect that the introduction of female labour into professional spheres will prove a greater boon either to the aspirants themselves or to the nation than it has been in the factory and the workshop? A friend, of original habits of thought, points out* that upon man alone was laid the penalty of labour as upon woman the sorrow of child-bearing. This is in fact the very same lesson, clothed in theological language, which we learn from biology. Among the lower animals, who, as compared with man, may be called the proletariate† of creation, both sexes indeed seem merely or mainly to exist in order to perpetuate

* Genesis iii., 16, 17.

† As applied to the human species we consider this term eminently foolish. The man who benefits his race in no other way will probably injure it by leaving posterity like himself.

their species. Still, even here, the female is more exclusively constructed for and more totally absorbed in the task of reproduction than the male. The share of the latter in this function is, strictly speaking, momentary, whilst during the stage of maturity the energies of the normal female are more or less completely devoted to the nurture, intra- and extra-uterine, of her offspring. Even when she never becomes a mother the generative system exercises a modifying influence upon her whole career. This consideration throws a strong light upon the ground taken by certain of the more "advanced" female advocates of the movement. The *femme libre* of the new social order may, indeed, escape the charge of neglecting her family and her household by contending that it is "not her vocation to become a wife and a mother." Why then, we ask, is she constituted a woman at all? Merely that she should become a sort of second-rate man? We have already declared, and we repeat, that we wish a free career for every talent. If an abnormal woman possesses a man's muscular strength and adaptation for toil, we would not, either by law or by social influences, seek to debar her from working at the oar, or the forge, or even from wielding the policeman's truncheon or the soldier's rifle. But we would not calculate on such anomalies; we would not legislate for their special protection, or seek to increase their number. In a manner perfectly analogous, if a woman possesses the taste and the power for scientific research usually confined to men,—and far from common even among them,—we would not wish to restrain her from the cultivation of her peculiar faculties; but we would not foster the growth of such a class of females. We would not seek to entice women into the observatory, the laboratory, or, above all, into the dissecting-room, nor erect colleges for the training of *savantes*, any more than we would organise female regiments and open institutions where muscular young ladies might perfect themselves in the management of heavy artillery.

It is generally—too generally—assumed that every novelty, every change from what has hitherto been customary and recognised, commends itself, on the mere ground of its novelty, to men of science, as indeed to all unfettered inquirers, and will be resisted merely by those whose guiding principle is an unreasoning attachment to what is established. Never, perhaps, was it shown more clearly than with reference to the present question that innovation may be retrograde,—that a proposed change, if carried out, may involve a return to a lower stage of development. What is the very

essence of all advance to a higher stage of being, save differentiation? We see what was at first homogeneous, uniform in structure, become resolved into distinct tissues and members. We see functions, which in some rudimentary state were jointly exercised by the whole body of an animal, gradually allotted out to special organs, and during and in consequence of this very specialisation acquiring a far higher degree of perfection than they heretofore possessed. Look at the first rudimentary state—germ, seed, or ovum—of the plant or animal, and compare it with the mature organism to which it ultimately gives rise. What was one has become manifold; what was simple is now highly complex. The globule of albuminoid matter has developed into distinct members — sense-apparatus, organs respiratory, digestive, circulatory, locomotive, &c.—each of which has a separate task to fulfil, and is distinctly organised for that very purpose. It is no departure from our subject to remark that though in the organic body one organ may, under certain circumstances, undertake the duties of another, such vicarious action involves grave peril to the organ concerned and to the entire animal. Perhaps the world may yet find that the analogy between the individual and mankind holds good in this respect, and that a social congestion may follow from the movement we are examining.

To return: the increase of size which distinguishes the butterfly from the egg, or the oak from the acorn, is a trifling feature compared with the accompanying differentiation—chemical, morphological, and functional—which has taken place.

If we pass from a consideration of the individual plant or animal to a survey of the entire organic realms we find, as we advance from the humblest and meanest beings to the highest, merely a repetition of the same great fact. At the one extremity of the scale—if this expression may still be used—we find beings whose senses, such as they are, must be exercised by the whole external surface of the body, those more special functions which we know as sight, hearing, &c., being still identical with feeling. No distinct nervous system, still less definite nerve-centres, can be traced. Nor are there any organs specially devoted to the processes of respiration, circulation, digestion, &c. A common internal cavity takes the place, and in a crude way fulfils the duties of all these parts. Externally the same uniformity prevails; there are no limbs, no members exclusively constructed for locomotion in any of its modes, or for prehension. The animal moves by elongating and contracting its whole body,

or by rolling over. In many of the lower forms of animal life the sexes are not separated, the functions of the male and the female being exercised by one and the same individual. It is a fact long familiar to the world that the polype may be cut into without injury, each part soon becoming a complete animal.

To such simplicity of structure the completest contrast is afforded by the higher animals. Throughout their bodies we find a "division of labour," each function having its organ and each organ its distinct function. To trace how this differentiation is carried out would be wearisome, and, being admitted, is fortunately needless.

It may be useful, however, to call to mind the fact that animals which when mature are broadly and easily distinguished from each other, are more and more alike the earlier the stage of growth at which we institute a comparison. The differences between a baby chimpanzee and a human infant are much slighter than those between the adults of the respective species. If we extend our researches to the embryonic state we find that the rudimentary man can scarcely be distinguished from many of the other vertebrates. It is only, as Prof. Huxley points out, in the later stages of pre-natal growth that the human fœtus differs from that of an ape. In the former the convolutions of the brain, according to Prof. Bischoff, reach about the same stage of development as in an adult baboon. The great toe, in man, is considered by Prof. Owen the most characteristic feature of the human skeleton; but in an embryo about an inch in length Prof. Wyman found this member not lying parallel with the other toes, but projecting out from the side of the foot as it does permanently in the so-called Quadrumana in their mature condition. Thus plainly does it appear that differentiation is the way to perfection, each animal as it approaches maturity diverging more and more from other forms, from which in its earlier stages it was scarcely distinguishable.

Yet again, we may turn from a survey of the growth of the individual, and from a comparison of the highest and lowest forms of contemporary organic life, to the consideration of the successive phases of being that have peopled our earth. Here, too, we find the same great law prevail. In the remote past we find what are called "generalised forms,"—animals which seem to have combined in themselves the rough outlines of what we now find developed into perfectly distinct beings.

Suppose it were now proposed as an improvement in the

structure of man, or of any other mammalian species, that the functions now exercised by two distinct organs—such as, *e.g.*, the eye and the ear, or the nerves of motion and of sensation—should be "lumped" together, committed to one only set of organs; would such a change, if we for the moment suppose it practicable, be an advance or a retreat? Would it raise or lower the species in the scale of existence? It might seem a convenience if, instead of seeing with our eyes alone, we could also see and hear with our ears; but would either the seeing or the hearing be done as well as now, when each is the sole function of an express organ? On the principles of the old Natural History, as well as of the New, we may safely reply in the negative. The change we have supposed is fortunately incapable of being effected, otherwise the attempt would doubtless be made in the name of "progress."

But we may follow the principle of Differentiation, and trace its workings over the boundaries of Biology into those of Sociology, if such a science can be said to exist. Where differences of structure can no longer be traced we still find differences of function. In man we find no variation in the number and position of bodily organs; yet identical organs in different individuals are trained to special tasks which to other men would be impossible, and which might seem to necessitate a structural difference. We come, that is to say, upon the division of labour, which is one of the most characteristic and essential features of civilisation. We have seen that in the lowest forms of animal life the entire body seemed to subserve every vital process; just so in the lowest stages of human society, every individual is at once warrior, hunter, builder, maker of arms and other utensils, and—in as far as agriculture is practised at all—tiller of the soil. Every man is perforce, in the words of the adage, "Jack of all trades," with the inevitable consequence that he is "master of none." In a civilised nation, just as in the higher animals, all this is reversed. Every function has its special organ, or, in other words, every task is committed to a separate man or body of men. In all this we can trace out nothing that speaks of arbitrary interference or compulsion. In the animal or human body each function is committed to organs fitted for that function. The stomach does not protest because it is not the seat of respiration, nor does the heart crave to undertake the task of digestion, either instead of or along with its own duties. In human society—complain as we may about "square pegs" being placed in "round holes"—the different tasks are in the main

assigned to the men most competent for their performance. In a savage tribe the strongest and bravest naturally leads in war; the man keenest of eye and ear becomes the scout, either as regards hostile tribes or beasts of the chase. The wisest and most eloquent—attributes which if necessarily connected in primitive times are now so no longer—took the foremost place in council. The man of greatest manual dexterity would be chief bow-maker to the tribe. The process in operation was, in fact, Natural Selection. The man who undertook a task for which he was unfitted, or less fitted than others, was gradually eliminated, as far as that particular task was concerned. In proportion as new wants sprung up and new means of gratifying them were devised, social functions were multiplied, and the division of labour became more minute. Yet even in the very rudest state, as far at least as anthropologists have been able to trace, there never was a time when the duties of all persons were absolutely identical. To men and to women different duties were assigned on the same principle of Natural Selection. Changes have, indeed, taken place in the distribution of the tasks respectively allotted to the two sexes. But these changes, it is important to note, till the "woman's-rights' movement sprung up, have all been in one direction—the direction of increasing differentiation. The distinction between men's work and women's work has been increased, not diminished. The barbarian and the semi-civilised nation allowed women to carry heavy burdens, to tug at the oar, to wield the spade, the hoe, the mattock in the fields, and even to labour in mines. In our higher civilisation such tasks are limited to man, and, as we have already remarked, to abnormal "mannish" women. The movement we are considering, in so far as it aims at breaking down the natural barriers between the duties of the two sexes, is palpably retrograde. If advancement towards perfection is reached by differentiation, *anti-differentiation*,—if we may use the expression,—whether structural or functional, must be a return to a lower condition. If the first and plainest step in the division of labour is to be abandoned, how can others be maintained?

It has been already pointed out in the "Quarterly Journal of Science" that among vertebrate animals the social unit of which nations are put together is the family, whether that be monogamous or polygamous. A community of rooks is made up of an assemblage of married couples. A tribe of baboons consists of a number of males, each one having his wives and offspring. Now the "woman's-rights' movement"

not merely runs counter to Nature in the respects we have already shown, but it is open to the charge of seeking to destroy family life and to constitute society of individuals—of atoms instead of molecules. In so doing it tends towards the condition of things prevalent in certain insect-communities. But there the mass of the nation, and especially its working and fighting members, is composed of what are commonly called neuters. Of such an arrangement no trace prevails among vertebrate animals, and we do not therefore see how their example can afford us any practical precedent.

We have therefore, in fine, full ground for maintaining that the "woman's-rights' movement" is an attempt to rear, by a process of "unnatural selection," a race of monstrosities—hostile alike to men, to normal women, to human society, and to the future development of our race. We know that the modern "honorary secretary" is always ready to exclaim "Let heaven and earth perish, so my crotchet may be realised." But we would bid him ask himself whether the end is worth the means?

IV. WHAT IS A FLOWER?

By F. T. Mott, F.R.G.S.

IT is admitted that a complete flower consists of four parts or whorls, viz., the pistil, the stamens, the corolla, and the calyx; but it is maintained that the *essential* parts are the pistil and stamens only. The Monochlamydeæ, in which the corolla is absent, and even the Achlamydeæ, which have neither corolla nor calyx, are still included among Flowering Plants.

The technical rules by which this conclusion is arrived at are, first, that in classification organs which are universal have more value than those which are sometimes wanting; and, secondly, that fertilisation by pollen is more complex, and therefore of higher value than fertilisation by antherozoids.

For the mere purpose of classification these rules are probably sound, but at the same time they hide from us one view of Nature which is a truer and more interesting view

than that which they present to us. They help to make us familiar with the *results* at present attained, but they blind us to the *processes*, to the laws of perpetually changing life which have given to the vegetation of the world a different aspect from age to age.

In order to classify results we give the highest value to characters which are most fixed and permanent, and these are to be found in the organs which are earliest developed and most universal. But in order to see what Nature is doing, and what she promises to do,—what point she has reached, and what is likely to be her next step forward,—we must look not to the old and permanent, but to the new and the changing.

There is scarcely anything more permanent in a plant than its organs of reproduction: the forms which these assume are therefore of high value in the distinction of genera and species. It is true, also, that when these organs take the form of pistil and stamens they are more complex than, and show a decided advance in development over, the lower and simpler form of archegonium and antheridium. On these grounds it is correct to distinguish pollen-bearing from antherozoid-bearing plants, and convenient to use the variations in pistils and stamens as permanent marks of genera and species.

But is it correct to make "pollen-bearing" synonymous with "flowering," and to regard pistil and stamens as the essentials of a flower, calyx and corolla as only accessories?

There is an immense difference in appearance between a rose and a catkin, between the "flower" of an iris and the "flower" of a grass. A large part of the beauty of the world and the poetry of life would be blotted out if plants had no corolla. Can it be true that this last and loveliest outcome of vegetative force is a mere superfluity? a bit of meretricious tinsel just put on by a few clever plants to catch bees and butterflies, as a girl uses a bright ribbon to catch wandering eyes? But the girl's best and most attractive ornament, after all, is her face, which was made by no art of hers. Like the flower, it is the inevitable product of internal forces, ordained from the hour of birth—the loveliest thing in all the world. And is the beauty of womanhood only a lure for men?

Let the following arguments be fairly weighed:—

1. Reproductive organs are common to all plants of every grade, and the process of fertilisation is essentially the same whether it be by antherozoids or by pollen. Reproductive organs do not, therefore, in themselves constitute a flower

unless *all* plants have flowers. But if the archegonium of a moss and the catkin of the hazel are flowers, we surely want another name for the rose and the lily. Yet it is these which have the prescriptive right to that name. The rose is a flower to all people and in all tongues. The name has been appropriated by botanists to the reproductive organs of other plants on the assumption that these were the essential objects which it represented, but the popular voice has never confirmed the act. The child who gathers buttercups and daisies with delight repudiates docks and sedges as "weeds," not "flowers." This popular nomenclature is not necessarily right, but it shows that there is a marked distinction which botanists have perhaps not sufficiently regarded.

2. Plants do not exist for the *purpose* of reproduction. It seems to be very generally assumed that when a plant has perfected seed it has accomplished the object of its life: this is surely a mistake. Reproduction is a means, not an end; the means by which the continuation of the race is secured through generations of perishing individuals. The life of the individual is maintained by food, the life of the species by reproduction, which means the carrying forward of potential energy, from generation to generation, with gradual accumulation during the development of a species and gradual loss during the period of dying out. But as the individual does not live for the mere purpose of feeding, so the species does not live for the purpose of being reproduced. It may be said, rather, that both the individual and the species exist because the condition of the ever-moving and ever-changing Force—whose movements and changes are precisely recorded and represented by the movements and changes of Matter—produces, at this epoch, effects of that particular kind. Whether that Force be voluntary or involuntary, this is the "final cause" of all things as far as human reason can discover.

The motions of Force being wave-motions, the life of both individual and species is of the nature of a wave, and has its gradual accumulation, concentration, and climax, and then its gradual decline, dissipation, and extinction.

Assimilation of food and reproduction are necessary incidents in this process, but the cause is the existence of the Force-wave, and the ultimate end of that wave is the attainment of its climax, its maximum of concentration and unification.

The climacteric of individuals is attained at various stages, according to the position of the individual wave in the great specific or ordinal wave. There are Fungi and Algæ which

never attain to any development beyond the embryonic cellular tissue; ferns which develop early forms of vascular tissue; Conifers reaching the higher stage of wood-formation; oaks and alders, poplars and willows attaining to the leaf stage;—and beyond these, what? The true flower-bearers, the dichlamydeous phanerogams, whose life-wave—passing through all the earlier stages of cell, wood, and leaf—attains to the development of corolla, and floods the world with a glory of colour previously unknown.

3. The corolla of nearly all flowers, when first formed in the bud, is of a pale greenish tint. The cells are filled with protoplasm, partly fluid, and partly granular in the form of chlorophyll. As the bud swells, the cells of the corolla are rapidly enlarged, at the expense of their contained protoplasm. If the protoplasm is entirely exhausted in this process, the cells, when the flower opens, are empty or filled with a thin transparent fluid, and the corolla is *white*, from the total reflection and transmission of all the light which falls upon it, the intensity of the whiteness depending upon the smallness of the cells. If there is still protoplasm to spare when the corolla cells are developed, this surplus is differentiated into substances either fluid or granular, which give colour to the cells they occupy. In proportion to the quantity of this surplus will be the quantity and intensity of the colour.

Colour is of course produced by the absorption of certain constituent rays in the white sunlight, and the reflection of the remainder. The colours of flowers are nearly all *secondary* colours, combinations of two out of the three primaries, red, green, and violet. It is evident, therefore, that the colouring-matter in the cells is monochromatic—that it absorbs only one of the three primary colours, or at least that it absorbs one in much greater proportion than any other: and since the colours of flowers are mostly very bright, the quantity of any other colour absorbed must be small. The brightness of colour is in proportion to the absolute amount of light reflected to the eye. White light, which is a ternary compound, will always be brighter than any combination of portions of its constituents.

The secondary colours are brighter than the primaries, because they are composed of the combined light of two constituents instead of the single light of one.

Grey is a feeble white—a mixture of the three primaries, but not in quantities sufficient to give the effect of white.

Brown is a feeble yellow—a mixture of red and green in

small quantities. The green of summer foliage is the primary green of the spectrum with small additions of red and violet, producing yellow or blue greens.

The colours of the stems and branches of trees and shrubs are generally *browns* and *greys;* the foliage is *green,* and the flowers are *yellows, pinks,* and *blues.* In terms of the absorption of light these facts mean that in the stem and branches all the rays are absorbed, very little being reflected, violet least of any; that in the leaves *two* of the primaries are absorbed, while one is reflected; and that in the flowers one primary only is absorbed and two are reflected.

This change of condition in the colouring-matter at the three stages of development is in each case in the direction of greater concentration and unification. The polychromatic colouring-matter of the stem becomes dichromatic in the foliage and monochromatic in the flower.

The phenomena of light absorption are supposed to depend upon the molecular condition of the absorbing substance. Molecules appropriate the energy of those light-rays whose wave-lengths coincide with their own normal vibrations. In the stems of trees vibrations of all lengths are mixed together, and all the light-waves are absorbed. In the foliage the vital energy is concentrated in two forms of vibration only. In the flower concentration has been carried to its extreme limit. White flowers, which in the present era are as numerous as all the coloured flowers put together, are nevertheless, as flowers, in an *embryonic* stage. The protoplasm, the vital substance, has been exhausted in producing the petalous structure. There is not energy enough to fill the cells with living matter. These white-flowered species are in arrear of their coloured congeners, but some of them will probably in a future epoch attain the higher grade.

It is the special character of the centripetal wave of Vital Force to simplify relationships at each successive stage of development. This is seen in the external elements of a flower as well as in its internal structure. The arrangement of vascular bundles in the stem is not distinctly symmetrical. In the arrangement of leaves, however, there is a symmetry more or less evident, while in the flower there is a still greater concentration of parts and simplification of arrangement, so that symmetrical relationship is a striking feature and one of the main elements of floral beauty.

4. Flowers may exist, and do frequently exist, without

the reproductive capacity. Some species of violets produce their coloured and fragrant flowers in the spring, but these are barren, while the seed is produced in late summer from blossoms which contain the perfect stamens and pistils, but have no corolla. The Hydrangea and the cultivated Guelder-rose, with the majority of double-blossomed plants, carnations, roses, hawthorns, cherries, gorse, &c., must be excluded from the category of flowers if the reproductive function is taken as the distinguishing character. These plants, though luxuriant in growth and supremely beautiful, bear no seed when in their finest condition; they do not reproduce the species; the vital wave has reached in them its ultimate climax; the destiny of the species is fulfilled; there is no longer any necessity to carry forward the wave of Force from generation to generation. They have attained the beauty which marks maturity; reaction is about to set in; the wave would enter upon its descending phase, and the species would rapidly die out and disappear if it were not that man stays the dissipation of the wave by lateral propagation—a process analogous, perhaps, to that of preventing the dissipation of any given sound by inclosing it in a tube.

It is no answer to this argument to assert that the doubling of the flower, or the enlargement of the corolla at the expense of the stamens and pistil, or the conversion of the calyx into a coloured corolla, is an abnormal condition. Variation is universal. Abnormal variation is only such as exceeds the average limit. Alter the surroundings, or increase the energy of the wave, and the average changes; what was before abnormal is now normal. Abnormal variations, when they are due to accumulating energy, are prophecies of future development. A wild stock will just exist and perpetuate its species in poor soil crowded with competitors. Give it more air and food, and its growth will be more luxuriant, and its flowers larger and brighter. Remove it to the garden, supply it with the most favourable conditions for accumulating energy, and some of its flowers will produce a fifth petal. Select the seed which these flowers leave behind them, and you will at last get the beautiful but barren double stocks. Each change has been due to the same cause, augmented energy, and no one is more abnormal than the others.

The double flower is not the result of disease, but of accumulated energy. Diminish the energy, and you get palpable degradation in size or colour, or both. When Aphides attack the heads of wild honeysuckle the flowers

are small and *green*. The change of the protoplasm from a dichromatic to a monochromatic condition has not been effected, for want of vital energy. The phenomenon of increased blossom arising from checked growth is merely the result of a transfer of energy from one of the great secondary waves to another. The splendid flowers of many monocotyledons have probably been hastened towards maturity by the almost total suppression of the osseous secondary wave. The energy not used in the formation of stem and branches has been concentrated upon the blossom. Dr. Masters records that when *Kerria Japonica* was first introduced into Europe it bore single flowers, but in a few years every existing plant had become double-blossomed. Doubtless the change of climate hastened its development, brought the wave rapidly to its climax, and, of course, the species would have died out in Europe but for artificial propagation.

The average energy in those wild plants which bear coloured flowers is, at this epoch, sufficient to produce monochromatic protoplasm in one whorl only. An increase of energy brings the other whorls into the same condition, and the flower is doubled.

5. Flowers, then, are the ultimate term in that wonderful series of biological phenomena exhibited in the Vegetable Kingdom. Their essential characters are—concentration of external parts producing visible symmetry, and of internal energy producing monochromatic protoplasm, or, as in white flowers, the absence of protoplasm, from defect of energy at the moment of consummation. The reproductive organs associated with them are imperfectly developed petals, whose office is to carry on the specific wave until it reaches that point of concentration at which these organs also assume their ultimate character, when the doubled flower marks the fact that—in at least that place and time—the last of the four great secondary waves has reached its climax. When the species everywhere attains the same condition, that specific wave is about to enter upon its descending phase, and the species will shortly disappear.

It is probable that we can as yet form no conception of the splendour which flowers are destined to bestow upon this world in some far-off future age. We are yet in the epoch of foliage rather than of blossom; and beautiful as this is in its varied forms and tints, from tender spring to gorgeous autumn, when the flowers open and the brilliant secondary colours flash out amidst the primary green, we own that a new glory has been conferred upon the beautiful earth.

We collect in our gardens and conservatories the richest flowers that are scattered here and there through northern plains and tropic forests, but the "coming race"—whether of man or of some higher type of being—shall behold the earth one magnificent conservatory, one universal garden, and the music of colour shall become a familiar art.

V. GENESIS OF MATTER.

ASTRONOMERS have played with world-making, and mechanicians and mathematicians have laboured to do and to undo the movements of heavenly bodies, and in some departments probably the conclusions are final, but there is much left undone, and to chemists belongs a great portion both of work and imagination. To make a world chemically we must begin with chaos. I shall not attempt to go farther back to-day, but who knows where the imagination will venture? We must begin with disorderly masses. There must be no gravitation; that introduces order at once, and commands the attention of all that part of creation which exists in the form of that which we call Matter. It gives the commands "Stand still" or "Move on," to the greatest and smallest of the bodies which we know, with a calmness and inflexibility that no one attempts to resist. There must be no cohesion, or a large amount of order would exist; but, in small and numerous communities, a collection of villages like a region inhabited by savages; and this may have been a stage—who can tell? There must be none of our elements, because they all gravitate; and this wild condition of things we can only imagine by analysing the present.

Of course we begin with hydrogen, as apparently least composite. The belief is that this as a gaseous body is at least a compound of its own particles; in other words, that the ultimate parts of hydrogen do not keep isolated, but show their love of combination by forming molecules. Afterwards there is very little inclination visible to unite under ordinary temperatures. Let us suppose a molecule—or, if it pleases better, an atom—of hydrogen put into a jar containing nothing beyond that which fills a vacuum. No

"wild bull with fireworks on its horns and eagle gnawing at its back" will ever rage so violently; it will strike the side thousands of times in a second, and according to some it will continue to do this for ever and ever. Nay, is it not true that Force is immortal, and this motion must go on for ever. An eminent thinker has put this forward as a fundamental characteristic of atoms, that each, although formed out of the original material, has impressed upon it a peculiar motion, which is its personality, and constitutes its individuality and peculiarity as an element. That may be so in a sense, but it is not the gaseous motion which is the original creation, for that we know ceases, unless we can prove the same quality of motion to be existing even when the gaseous state ceases. And, after all, what is an atom separate from its motion? Is it not true that Force and Matter are one—that Matter moves by its own intrinsic and eternal quality of motion? The exact motion of gases is not eternal; the same frantic atom of hydrogen will stop its violent movements, give them up with one mighty gasp, —and so far as we know will never resume them,—and apparently on slight provocation, by a touch of chlorine, of oxygen, or of cold. Hydrogen, then, rages only under certain circumstances, dances only when motion is put into it; its motion is not eternal and unchangeable; it may be frozen into a liquid; it may be made into a solid, for ever inactive, and, like any poor piece of stolid matter, it may lie for ever dead. True you may give it life again, and it will dance on as merry as before; but the life must come to it.

Some people think that this gaseous motion is a perpetual one, and that they have at last discovered it in gases; but no—the fire seems to be required to keep up the motion of the hydrogen, as it keeps up the motion of the steam-engine, and when that goes out both cease. Matter is very dead; it may, however, be eternal: this hydrogen may move about as long as it is supplied with heat, and there may be no change in it for ever. We cannot suppose it to wear on, to weary in its course, unless we find an analogy in the loss of heat, when it calms down, and by loss of heat finds rest. It is clear, then, that it is not a primitive quality of hydrogen to move for ever as a gas, only if it is set in motion it will move in a certain way. But when the motion ceases as gaseous motion, does it still go on in a liquid or solid? It may be so, but we have no real proof; and at any rate the motion, although of a fundamentally similar kind, cannot be identically the same. Nobody can imagine an atom doing anything but move, and so to keep up its

characteristics we are obliged to suppose some action. Let us imagine the contrary; must it not at least have a tendency to action such as we find in attraction? We may imagine this, but I fear it cannot have this inclination without some remaining heat; and if we take all the life—that is, the motion—we know of, and leave nothing to give a tendency till heat comes again, we imagine the motion to exist in the atom itself in one case, and only in the atom when heated up—that is, set in motion—in the other case. There must be a latent capacity in the atom, and that must be represented in some way. Is it in a form or in another motion?

Here we come to a very curious point. When the heat comes to the hydrogen, and motion begins, the heat may be inclined to say, "I only am the power; the hydrogen is nothing; matter is a dead thing, with which I play as I choose." But we may answer the heat thus:—"Cause oxygen to move in exactly the same way, and I will believe you; or cause any other element to do the same." The heat cannot, because each has its own peculiar movement; and so we learn that hydrogen, after all, did play its part in the dance, and played it too with a power that seemed to be eternal. Although it cannot act alone, it can wait for endless ages for a companion with whom to rejoice—that is, take the heat away, freeze it to the utmost, and the particles will cease. At least I assume this; if indeed the existence of solid hydrogen, even for an instant, is not a sufficient proof. If any one says that heat is held too much as a material here, the reply is, "No, it is treated as an external agent." The hydrogen deprived of heat will be quite still so far as we know, and it is interesting to know in what condition it rests. It is not dead, but sleeps; its particles are closely associated, and the colder it is the more firmly do the particles unite—up to a certain point, at least, I for one do not know how far. After all, this is not death; in death there are no bonds of brotherly love. Can any one measure the strength of union of such particles, and find if there is more force expended by this hydrogen when it is active than when it is passive or void of heat? This to some extent we can do, although we cannot do it perfectly till we know the cohesive force, and a few more points, more clearly. But if, by the want of heat, there is this enormous power of compression—or, in other words, of attraction for itself—developed, then it would appear as if the original power of the hydrogen were enormous, and the heat did not increase it, but merely altered its direction. We must,

however, remember that there is a difference in the forces; the one is energetic—the gas will move of itself; the solid will not. Yet here we come to a stand—we have abundant force in the dead hydrogen. Can nothing else bring it out but heat? Can nothing cause it to burst forth of itself, and convert its terrible grip into activity? Who knows but the cold may overdo its work, and break up the hydrogen itself, when the earlier elements may spring out and convert that deadly grip into the gay dance of life and a new creation? If any one says that this is only a mode of manufacturing heat out of cold, I will say I know the objection, and I will stop this direction for the present and go elsewhere, assisted by a little imagination.

If we desire to rob hydrogen of more of its qualities we must break it up. Do we not see that the more it unites the more varied is its activity, and the more many-sided is its life? Let us break it into more simplicity, and remove its powers; let us say "Hydrogen become simple, whatever that be,"—either the one matter, the *vera substantia* of all things, or at least something even more ready to escape than hydrogen is in a state of gas. For this we need a new power; we must pass the bounds of the known; we must find a force and split the hydrogen, tearing it asunder by aphairesis, and leaving a something or two somethings which have lost at least one of their powers, that of remaining together until some equal force unites them again. That which they have lost is, let us say first, affinity. If affinity is lost, why not gravitation also, of which it is but a branch? But by what right have you gone beyond the bounds of our matter? It is only a leap, and I shall return; but in my leap I saw that there was a something different from this earth, and the matter there did not gravitate. Indeed! and how can it be matter if it did not gravitate? I am not aware that gravitation is any necessary quality of matter. We can suppose matter without. Indeed there are various kinds of gravitation of one body to another, and much more powerful than that which we designate especially by the name of Gravity. But this I said in a previous essay, in part. A magnet has another gravitation in it, which may go out of it; why may not our common gravitation be put out also? It is a mere fancy that it is necessary. But how did hydrogen obtain its gravitation? How does any body obtain a new property? It is by intrusion of other things, arts, and conditions, as new races are formed; and hydrogen most probably obtained its gravitation either by the combination which first made it hydrogen

or in some of the stages. Probably there were more than one stage; by going back we may suppose the one above spoken of, whereby it lost its cohesion in the greatest cold, its tendency to itself; and by another, its tendency to any other matter or its gravity; and thus we have its free parts in the wide Universe—and what are these parts of hydrogen like?

Now, do not wonder that hydrogen should have parts. Do you suppose that such a complex substance—yes, complex, it has many properties—was made at once? Nature makes the complex out of the simple. Hydrogen must be supposed capable of being broken up. The parts are not to be explained by experiment; we have no experience of the chemistry of the lower stage of matter. In the present known hydrogen we have atom striking against atom, and interrupted in its motion; we have also atom combining with atom, and more interrupted; and we have atom gravitating towards atom, seeking a fresh stage of interruption, and a complex social system that cannot be kept up by the simple savage atoms of the early stages of existence. These earlier atoms may have no community of feeling. We suppose the great gravitation of the Universe as nothing to them, and that they live unconscious by their acts of any existence outside of them. Of course some people will say that in any case they cannot pass through our matter: that is quite an assumption. Glass allows something to pass, and why not our more simple bodies? We are not quite sure whether the same does not in some way take place with all matter which is transparent to several agencies.

And now that you have your free and independent matter, what will you do with it? I cannot catch it and curb it; it will not yield to my entreaties, or be kept down by my chains. Hydrogen would blow against me; this will not. Hydrogen would burn, and even sing in doing so; but this will not. And yet I cannot consider it without qualities as to hydrogen itself. The world sought it thousands of years, but could not catch it. By itself it will do nothing but escape from us. After a long time it was found that by combining with oxygen it burnt, and greater firmness was given to both. By analogous means may one element receive new qualities, such as weight and resistance. But we do not suppose that the removal of gravitating power removes all resistance. That is not necessary, as cohesion is much more powerful than gravitation; but we have removed cohesion also from our new elements: they are free.

The difficulty now is to know in what relation this new, or rather primitive substance really stands to matter at all. We might say, in one aspect, as an iron magnet stands to a piece of iron. As a magnet it is powerful, and if nothing but iron were about it we should see greater influence; it lifts iron in spite of gravitation, and a few touches make it dead iron again. The space round the magnet is to iron as if it were solid and resisting. Is it irrational to suppose matter which fills space, and by a reversed relation turns all the space into a solid. It is no more wonderful; in wandering into past or distant nature the eye is unable to see clearly.

But, after all, is this not a mere repetition of Helmholz's idea. It may be like it in some respects, but not in all, and in this it is very different—he seems to understand the condition to which he reduces matter. I do not understand the state in which mine is; strange new conditions arise, and I need not say that I cannot see how his will work. I look only to certain analogies very safe for easy reasoning and pioneering.

Another objection seems to be that if you have brought matter to nothing your reasoning is of no use. I have brought it to nothing, or at least to a something which at first view seems next to it, that it may be seen how little it is without the breath of life put into it. Even the life called resistance is almost gone,—certainly all the life that we call usually material,—but give it combination and it may fall to the sun as hydrogen, and it may rave amongst oxygen to keep up our constant fires. Certainly it is a limited view that gives to our elements only primitive life, and that conceives them to be simple. Of course I use life analogically. Neptune never went to Greenland, so far as we know. Imagine him riding in his car, splashing through the ocean, and finding suddenly that he had got into a prison; the very water is held above him, his horse's hoofs are getting too cold to move, and to his astonishment the whole team become statues, and even he, the king, cannot control this new element, ice. Imagine him coming to Olympus and telling this wonderful tale, whilst Mercury said "You are confined in your movements; indeed I never heard before of your going outside the Pillars of Hercules. I am accustomed to go far, and in my movements among the stars I have come among similar stiffening of far finer matter than water, namely, that which flows in universal space. The messengers of the spheres have moved in the space as unconscious of the existence of anything present

as men of the ignorant class are of air, or as fish are of water, and they have been astonished when—as if at a signal—great darts of white have shot through the empyrean, each sending out other darts, until the whole became as solid as the seas of the Hyperboreans." "And why not?" said Vulcan; "most things melt by heat, but some things become lighter by becoming solid, and water, I think, is one of these, as I sometimes have occasion to observe when I seek the cooling snows of Olympus, or its solid ice, warming it to wash the soot off me before I come to supper. I have seen such things without going so far: have I not seen some men rejoicing in the soft winds of heaven, or the hills warmed and moistened by the sun and sea breezes, when suddenly Jove's thunders rolled, and the moisture fell down in heavy hail that struck the frightened people and their flocks, and endangered, if not destroyed, their lives? Why may not a touch of Jove's fire harden the unfathomed space itself as readily as a tender soul, by a change of thought, turns to rage and cruelty? or why may it not become so cold that even that may stiffen as the air itself, or something in it, which makes white the forests below us in a few hours?"

These Olympians were not sound chemists, and forgot that the total vapour was as heavy as the hail to which it turned; but your free matter, by your own account, must be very light, or rather bearing no weight it must be very thin at best. Its weight and thinness are not dependent on each other; its very power of dispersion shows that there is some force in it, and it is not yet reduced to nothing, and you will at least allow that there is plenty to draw from. And yet have I not sat, at a little distance, at a large louvre window, and looked on in the dim evening; the light seemed abundant, and nothing was observed to interrupt my view: the edges of the glass louvre strips were towards me, and after a while I began to see that there were thin lines; suddenly the space was obscured: there were no window-shutters, no gradual clouding. Had my eyes lost their power of seeing? A veil comes gradually: could it be a veil? No, it was a sudden reversal of the louvre. How much may be done by this, and how many analogies it leads to!

I suppose we all allow anything as a temporary fancy, and this I think may be considered, that the weight of a body is not a necessary quality, but entirely external to it. 2. That if so a time may have been when weight came into creation. 3. A condition may still exist of substance having

no weight. 4. We may imagine a place to exist where matter has no weight, but this is less easily conceived of common matter. 5. We may imagine weight to be taken out and in; we have an analogy in a magnet lying on the ground, attracting, and in a sense making heavier, the iron over it. 6. That something which gives weight may exist without our matter, although we cannot prove it. 7. If it is outside of our matter it may be an existence of a kind to be passing through our matter. 8. Possibly an existence polarising the vibrations, or rather movements, of molecules, and giving them a direction. 9. If so, it probably has a motion of its own. 10. If so, the parts of which it is composed are necessarily smaller than the atoms of our chemistry: it is as difficult to conceive it non-atomic as to conceive our matter to be so, and we do not render it more intelligible by calling it non-atomic. 11. The state of Physics and Chemistry demands a finer atom than ours, and we can get it best by breaking ours up. 12. If our atoms were as small as these supposed ones they would go through glass, and perhaps through all our common matter, as these finer are supposed to do. 13. If our so-called atoms are complex, they are probably compressible to a certain extent, and changeable in shape. 14. Atoms of more primitive form will be less so, and probably infinitely hard, as we have supposed ours to be, and as ours would be if they were primordial. 15. If there are any which by pressing forward cause common matter to gravitate, they themselves must, if they do not gravitate, have a power of direction. It is very hard to imagine this, although it has been supposed to have been explained. 16. If so, they cannot act merely on the surface, as the weight of a body does not depend on its surface; they may act on every atom, and when they penetrate our matter they can so act, and by this means we obtain a force immeasurably multiplied, *i.e.*, multiplied according to the number of atoms in a body. 17. These ideas connect the finer substance with our coarser matter; it is not fair quite to sever them; they do not, however, convert the finer matter into forces, because even that we can separate from force, and are compelled to do so by our reason.

We must some day think more of this.

VI. THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE British Association held its 1878 meeting at Dublin, in August last. This, the forty-eighth meeting of the Association, and the third visit it has paid to Dublin, was one of the most successful meetings ever held, the number of Members and Associates present being 2756. Mr. Spottiswoode, President, in his Address first made some remarks upon the purposes, operations, and prospects of the Association, of which he has been for many years the Treasurer. He then passed to the consideration of the external aspects and tendencies of Mathematical Science.

Viewed from a mathematician's own point of view, mathematics offer so few points of contact with the ordinary experiences of life or modes of thought, that any account of its actual progress must, he said, fail in the first requisite of an Address—namely, that of being intelligible. But although in its technical character mathematical science suffered the inconveniences, while it enjoyed the dignity, of its Olympian position, still in a less formal garb, or in disguise, it is found present at many an unexpected turn; and although some may never have learnt its special language, not a few have, all through their scientific life, and even in almost every accurate utterance, like Molière's well-known character, been talking mathematics without knowing it. It is, moreover, a fact not to be overlooked that the appearance of isolation, so conspicuous in mathematics, appertains in a greater or less degree to all other sciences, and perhaps also to all pursuits in life. In its highest flight each soars to a distance from its fellows. Each is pursued alone for its own sake, and without reference to its connection with, or its application to, any other subject. The pioneer and the advanced guard are of necessity separated from the main body, and in this respect mathematics does not materially differ from its neighbours. In his preface to the "Principia," Newton gives expression to some general ideas which may well serve as the key-note for all future utterances on the relation of mathematics to natural, including also therein what are commonly called artificial, phenomena:—"The ancients divided mechanics into two parts,

rational and practical; and since artizans often work inaccurately, it came to pass that mechanics and geometry were distinguished in this way, that everything accurate was referred to geometry, and everything inaccurate to mechanics. But the inaccuracies appertain to the artizan and not to the art, and geometry itself has its foundation in mechanical practice, and is in fact nothing else than that part of universal mechanics which accurately lays down and demonstrates the art of measuring." He next explains that rational mechanics is the science of motion resulting from forces, and adds,—"The whole difficulty of philosophy seems to me to lie in investigating the forces of nature from the phenomena of motion, and in demonstrating that from these forces other phenomena will ensue." Then, after stating the problems of which he has treated in the work itself, he says—"I would that all other natural phenomena might similarly be deduced from mechanical principles. For many things move me to suspect that everything depends upon certain forces in virtue of which the particles of bodies, through forces not yet understood, are either impelled together so as to cohere in regular figures, or are repelled and recede from one another."

Every subject, whether in its usual acceptation scientific or otherwise, may have a mathematical aspect; as soon, in fact, as it becomes a matter of strict measurement, or of numerical statement, so soon does it enter upon a mathematical phase. It is not so much elaborate calculations or abstruse processes which characterise this phase as the principles of precision, of exactness, and of proportion. These are principles with which no true knowledge can entirely dispense. If it be the general scientific spirit which at the outset moves upon the face of the waters, and out of the unknown depth brings forth light and living forms, it is no less the mathematical spirit which breathes the breath of life into what would otherwise have ever remained mere dry bones of fact, which reunites the scattered limbs and re-creates from them a new and organic whole.

Taking precision and exactness as the characteristics which distinguish the mathematical phase of a subject, we are naturally led to expect that the approach to such a phase will be indicated by increasing application of the principle of measurement, and by the importance which is attached to numerical results. And this very necessary condition for progress may be fairly described as one of the main features of scientific advance in the present day.

If, continued the President, it were my purpose, by

descending into the arena of special science, to show how the most various investigations alike tend to issue in measurement, and to that extent to assume a mathematical phase, I should be embarrassed by the abundance of instances which might be adduced. I will therefore confine myself to a passing notice of a very few, selecting those which exemplify not only the general tendency, but also the special character of the measurements now particularly required—viz., that of minuteness, and the indirect method by which alone we can at present hope to approach them. An object having a diameter of an 80,000th of an inch is perhaps the smallest of which the microscope could give any well-defined representation; and it is improbable that one of 120,000th of an inch could be singly discerned with the highest powers at our command. But the solar beams and the electric light reveal to us the presence of bodies far smaller than these. And, in the absence of any means of observing them singly, Professor Tyndall has suggested a scale of these minute objects in terms of the lengths of luminiferous waves. To this he was led, not by any attempt at individual measurement, but by taking account of them in the aggregate, and observing the tints which they scatter laterally when clustered in the form of actinic clouds. The small bodies with which experimental science has recently come into contact are not confined to gaseous molecules, but comprise also complete organisms; and the same philosopher has made a profound study of the momentous influence exerted by these minute organisms in the economy of life. And if, in view of their specific effects, whether deleterious or other, on human life, any qualitative classification, or quantitative estimate, be ever possible, it seems that it must be effected by some such method as that indicated above. Again, to enumerate a few more instances of the measurement of minute quantities, there are the average distances of molecules from one another in various gases and at various pressures; the length of their free path, or range open for their motion without coming into collision; there are movements causing the pressures and differences of pressure under which Mr. Crookes's radiometers execute their wonderful revolutions. There are the excursions of the air while transmitting notes of high pitch, which through the researches of Lord Rayleigh appear to be of a diminutiveness altogether unexpected. There are the molecular actions brought into play in the remarkable experiments of Dr. Kerr, who has succeeded, where even Faraday failed, in effecting a visible rotation of the plane of polar-

isation of light in its passage through electrified dielectrics, and on its reflection at the surface of a magnet. To take one more instance, there are the infinitesimal ripples of the vibrating plate in Mr. Graham Bell's most marvellous invention. Of the nodes and ventral segments in the plate of the telephone which actually converts sound into electricity and electricity into sound, we can at present form no conception. All that can now be said is that the most perfect specimens of Chladni's sand figures on a vibrating plate, or of Kundt's lycopodium heaps in a musical tube, or even Mr. Sedley Taylor's more delicate vortices in the films of the phoneidoscope, are rough and sketchy compared with these. For notwithstanding the fact that in the movements of the telephone-plate we have actually in our hand the solution of that Old World problem, the construction of a speaking-machine, yet the characters in which that solution is expressed are too small for our powers of decipherment. In movements such as these we seem to lose sight of the distinction, or perhaps we have unconsciously passed the boundary between massive and molecular motion. Through the phonograph we have not only a transformation, but a permanent and tangible record of the mechanism of speech. But the differences upon which articulation (apart from loudness, pitch, and quality) depends appear from the experiments of Fleeming Jenkin, and of others, to be of microscopic size. The microphone affords another instance of the unexpected value of minute variations—in this case of electric currents; and it is remarkable that the gist of the instrument seems to lie in obtaining and perfecting that which electricians have hitherto most scrupulously avoided, viz., loose contact. Once more, Mr. De la Rue has brought forward, as one of the results derived from his stupendous battery of 10,000 cells, strong evidence for supposing that a voltaic discharge, even when apparently continuous, may still be an intermittent phenomenon; but all that is known of the period of such intermittence is, that it must recur at exceedingly short intervals. And in connection with this subject it may be added that, whatever may be the ultimate explanation of the strange stratification which the voltaic discharge undergoes in rarefied gases, it is clear that the alternate disposition of light and darkness must be dependent on some periodic distribution in space or sequence in time which can at present be dealt with only in a very general way. In the exhausted column we have a vehicle for electricity not constant like an ordinary conductor, but itself modified by the passage of the discharge, and perhaps sub-

ject to laws differing materially from those which it obeys at atmospheric pressure. It may also be that some of the features accompanying stratification form a magnified image of phenomena belonging to disruptive discharges in general; and that consequently, so far from expecting among the known facts of the latter any clue to an explanation of the former, we must hope ultimately to find in the former an elucidation of what is at present obscure in the latter. A prudent philosopher usually avoids hazarding any forecast of the practical application of a purely scientific research. But it would seem that the configuration of these striæ might some day prove a very delicate means of estimating low pressures, and perhaps also for effecting some electrical measurements. Now, it is a curious fact that almost the only small quantities of which we have as yet any actual measurements are the wave-lengths of light; and that all others, excepting so far as they can be deduced from these, await further determination. In the meantime, when unable to approach those small quantities individually, the method to which we are obliged to have recourse is, as indicated above, that of averages, whereby, disregarding the circumstances of each particular case, we calculate the average size, the average velocity, the average direction, &c., of a large number of instances. But although this method is based upon experience, and leads to results which may be accepted as substantially true; although it may be applicable to any finite interval of time, or even any finite area of space (that is, for all practical purposes of life), there is no evidence to show that it is so when the dimensions of interval or of area are indefinitely diminished. The truth is that the simplicity of Nature which we at present grasp is really the result of infinite complexity; and that below the uniformity there underlies a diversity whose depths we have not yet probed and whose secret places are still beyond our reach.

The President then proceeded to make special remark on some processes peculiar to modern mathematics: he selected for examination three methods, in respect of which mathematicians are often thought to have exceeded all reasonable limits of speculation, and to have adopted for unknown purposes an unknown tongue, with the view of showing that not only in these very cases mathematical science has not outstepped its own legitimate range, but that even art and literature have unconsciously employed methods similar in principle. The three methods in question are—first, that of Imaginary Quantities; secondly, that of Manifold Space;

and thirdly, that of Geometry not according to Euclid. He explained Imaginary Quantities as follows;—

To fix our ideas, consider the measurement of a line, or the reckoning of time, or the performance of any mathematical operation. A line may be measured in one direction or in the opposite; time may be reckoned forward or backward; an operation may be performed or be reversed, it may be done or it may be undone; and if having once reversed any of these processes we reverse it a second time, we shall find that we have come back to the original direction of measurement or of reckoning, or to the original kind of operation. Suppose, however, that at some stage of a calculation our formulæ indicate an alteration in the mode of measurement such that, if the alteration be repeated, a condition of things not the same as, but the reverse of, the original will be produced. Or suppose that, at a certain stage, our transformations indicate that time is to be reckoned in some manner different from future or past, but still in a way having definite algebraical connection with time which is gone and time which is to come. It is clear that in actual experience there is no process to which such measurements correspond. Time has no meaning except as future or past; and the present is but the meeting point of the two. Or, once more, suppose that we are gravely told that all circles pass through the same two imaginary points at an infinite distance, and that every line drawn through one of these points is perpendicular to itself. On hearing this statement we shall probably whisper, with a smile or a sigh, that we hope it is not true; but that in any case it is a long way off, and perhaps, after all, it does not very much signify. If, however, as mathematicians we are not satisfied to dismiss the question on these terms, we ourselves must admit that we have here reached a definite point of issue. Our science must either give a rational account of the dilemma or yield the position as no longer tenable. Special modes of explaining this anomalous state of things have occurred to mathematicians. But, omitting details as unsuited to the present occasion, it will, I think, be sufficient to point out in general terms that a solution of the difficulty is to be found in the fact that the formulæ which give rise to these results are more comprehensive than the signification assigned to them; and when we pass out of the condition of things first contemplated they cannot (as it is obvious they ought not) give us any results intelligible on that basis. But it does not therefore by any means follow that upon a more enlarged basis the formulæ are incapable

of interpretation; on the contrary, the difficulty at which we have arrived indicates that there must be some more comprehensive statement of the problem which will include cases impossible in the more limited, but possible in the wider, view of the subject.

If, both in geometry and in algebra, we occasionally make use of points or of quantities which from our present outlook have no real existence, which can neither be delineated in space of which we have experience, nor measured by scale as we count measurement; if these imaginaries, as they are termed, are called up by legitimate processes of our science; if they serve the purpose not merely of suggesting ideas, but of actually conducting us to practical conclusions; if all this be true in abstract science, I may, perhaps, be allowed to point out, in illustration of my argument, that in art unreal forms are frequently used for suggesting ideas, for conveying a meaning for which no others seem to be suitable or adequate. Are not forms unknown to biology, situations incompatible with gravitation, positions which challenge not merely the stability but even the possibility of equilibrium—are not these the very means to which the artist often has recourse in order to convey his meaning and to fulfil his mission? Again, if we turn from art to letters, truth to nature and to fact is undoubtedly a characteristic of sterling literature; and yet in the delineation of outward nature itself, still more in that of feelings and affections, of the secret parts of character and motives of conduct, it frequently happens that the writer is driven to imagery, to an analogy, or even to a paradox, in order to give utterance to that of which there is no direct counterpart in recognised speech.

Passing to the second of the three methods—viz., that of manifold space—Mr. Spottiswoode remarked that our whole experience of space is in three dimensions, viz., of that which has length, breadth, and thickness; there is, however, another aspect under which even ordinary space presents to us a fourfold, or indeed a manifold, character. In modern physics space is regarded not as a vacuum in which bodies are placed and forces have play, but rather as a plenum with which matter is co-extensive. And from a physical point of view the properties of space are the properties of matter, or of the medium which fills it. Similarly, from a mathematical point of view, space may be regarded as a *locus in quo*, as a plenum, filled with those elements of geometrical magnitude which we take as fundamental. These elements need not always be the same. For different purposes different ele-

ments may be chosen; and upon the degree of complexity of the subject of our choice will depend the internal structure or manifoldness of space. Thus, beginning with the simplest case, a point may have any singly infinite multitude of positions in a line, which gives a onefold system of points in a line. The line may revolve in a plane about any one of its points, giving a twofold system of points in a plane; and the plane may revolve about any one of the lines, giving a threefold system of points in space. Suppose, however, that we take a straight line as our element, and conceive space as filled with such lines. This will be the case if we take two planes,—*e.g.*, two parallel planes,—and join every point in one with every point in the other. Now the points in a plane form a twofold system, and it therefore follows that the system of lines is fourfold; in other words, space regarded as a plenum of lines is fourfold. The same result follows from the consideration that the lines in a plane, and the planes through a point, are each twofold. Again, if we take a sphere as our element we can through any point as a centre draw a singly infinite number of spheres, but the number of such centres is triply infinite; hence space as a plenum of spheres is fourfold. And, generally, space as a plenum of surfaces has a manifoldness equal to the number of constants required to determine the surface. Although it would be beyond our present purpose to attempt to pursue the subject further, it should not pass unnoticed that the identity in the fourfold character of space, as derived on the one hand from a system of straight lines, and on the other from a system of spheres, is intimately connected with the principles established by Sophus Lie in his researches on the correlation of these figures. If we take a circle as our element we can around any point in a plane as a centre draw a singly infinite number of circles; but the number of such centres in a plane is doubly infinite; hence the circles in a plane form a threefold system, and as the planes in space form a threefold system it follows that space as a plenum of circles is sixfold. Again, if we take a circle as our element, we may regard it as a section either of a sphere or of a right cone (given except in position) by a plane perpendicular to the axis. In the former case the position of the centre is threefold; the directions of the plane, like that of a pencil of lines perpendicular thereto, twofold: and the radius of the sphere onefold; sixfold in all. In the latter case the position of the vertex is threefold; the direction of the axis twofold; and the distance of the plane of section onefold; sixfold in all, as before. Hence space as a plenum

of circles is sixfold. Similarly, if we take a conic as our element, we may regard it as a section of a right cone (given except in position) by a plane. If the nature of the conic be defined, the plane of section will be inclined at a fixed angle to the axis; otherwise it will be free to take any inclination whatever. This being so, the position of the vertex will be threefold; the direction of the axis twofold; the distance of the plane of section from the vertex onefold; and the direction of that plane onefold if the conic be defined, twofold if it be not defined. Hence, space as a plenum of definite conics will be sevenfold, as a plenum of conics in general eightfold. And so on for curves of higher degrees. This is, in fact, the whole story and mystery of manifold space. It is not seriously regarded as a reality in the same sense as ordinary space; it is a mode of representation, or a method which, having served its purpose, vanishes from the scene. Like a rainbow, if we try to grasp it, it eludes our very touch; but, like a rainbow, it arises out of real conditions of known and tangible quantities, and if rightly apprehended it is a true and valuable expression of natural laws, and serves a definite purpose in the science of which it forms part. Again, if we seek a counterpart of this in common life, I might remind you that perspective in drawing is itself a method not altogether dissimilar to that of which I have been speaking; and that the third dimension of space, as represented in a picture, has its origin in the painter's mind, and is due to his skill, but has no real existence upon the canvas which is the groundwork of his art. Or, again, turning to literature, when in legendary tales, or in works of fiction, things past and future are pictured as present, has not the poetic fancy correlated time with the three dimensions of space, and brought all alike to a common focus? Or, once more, when space already filled with material substances is mentally peopled with immaterial beings, may not the imagination be regarded as having added a new element to the capacity of space, a fourth dimension of which there is no evidence in experimental fact?

The third method proposed for special remark is that which has been termed Non-Euclidean Geometry; and the train of reasoning which has led to it may be described in general terms as follows:—Some of the properties of space which on account of their simplicity, theoretical as well as practical, have, in constructing the ordinary system of geometry, been considered as fundamental, are now seen to be particular cases of more general properties. Thus a

plane surface and a straight line may be regarded as special instances of surfaces and lines whose curvature is everywhere uniform or constant. And it is perhaps not difficult to see that, when the special notions of flatness and straightness are abandoned, many properties of geometrical figures which we are in the habit of regarding as fundamental will undergo profound modification. Thus a plane may be considered as a special case of the sphere,—viz., the limit to which a sphere approaches when its radius is increased without limit. But even this consideration trenches upon an elementary proposition relating to one of the simplest of geometrical figures. In plane triangles the interior angles are together equal to two right angles; but in triangles traced on the surface of a sphere this proposition does not hold good. To this other instances might be added. The principle of representing space of one kind by that of another, and figures belonging to one by their analogues in the other, is not only recognised as legitimate in pure mathematics, but has long ago found its application in cartography. In maps or charts, geographical positions, the contour of coasts, and other features, belonging in reality to the earth's surface, are represented on the flat; and to each mode of representation, or projection as it is called, there corresponds a special correlation between the spheroid and the plane. To this might perhaps be added the method of descriptive geometry, and all similar processes in use by engineers, both military and civil.

With regard to pure and applied mechanics, it has often, said Mr. Spottiswoode, been asked whether modern research in the field of pure mathematics has not so completely outstripped its physical applications as to be practically useless; whether the analyst and the geometer might not now, and for a long time to come, fairly say, "Hic artem remumque repono," and turn his attention to mechanics and physics. That the Pure has outstripped the Applied is largely true; but that the former is on that account useless is far from true. Its utility often crops up at unexpected points; witness the aids to classification of physical quantities, furnished by the ideas (of Scalar and Vector) involved in the Calculus of Quaternions; or the advantages which have accrued to physical astronomy from Lagrange's Equations, and from Hamilton's Principle of Varying Action; on the value of Complex Quantities, and the properties of general Integrals, and of general theorems on integration for the Theories of Electricity and Magnetism.

These extensions of mathematical ideas would, however,

be overwhelming if they were not compensated by some simplifications in the processes actually employed. Of these aids to calculation I will mention only two, viz., symmetry of form and mechanical appliances; or, say, Mathematics as a Fine Art, and Mathematics as a Handicraft. And first, as to symmetry of form. There are many passages of algebra in which long processes of calculation at the outset seem unavoidable. Results are often obtained in the first instance through a tangled mass of formulæ. But almost within our own generation a new method has been devised to clear this entanglement. By Lagrange, and to some extent also by Gauss, among the older writers, the method of which I am speaking was recognised as a principle; but beside these perhaps no others can be named until a period within our own recollection. The method consists in symmetry of expression. In algebraical formulæ combinations of the quantities entering therein occur and recur; and by a suitable choice of these quantities the various combinations may be rendered symmetrical and reduced to a few well-known types. This having been done, and one such combination having been calculated, the remainder, together with many of their results, can often be written down at once, without further calculations, by simple permutations of the letters. Symmetrical expressions, moreover, save as much time and trouble in reading as in writing.

With regard to mechanical appliances, Mr. Babbage, when speaking of the difficulty of ensuring accuracy in the long numerical calculations of theoretical astronomy, remarked that the science which in itself is the most accurate and certain of all, had, through these difficulties, become inaccurate and uncertain in some of its results. And it was doubtless some such consideration as this, coupled with his dislike of employing skilled labour where unskilled would suffice, which led him to the invention of his calculating machines. Prof. James Thomson has recently constructed a machine which, by means of the mere friction of a disk, a cylinder, and a ball, is capable of effecting a variety of complicated calculations, which occur in the highest application of mathematics to physical problems. By its aid it seems that an unskilled labourer may, in a given time, perform the work of ten skilled arithmeticians. The machine is applicable alike to the calculation of tidal, of magnetic, of meteorological, and perhaps also of all other periodic phenomena. It will solve differential equations of the second, and perhaps of even higher orders. And through

the same invention the problem of finding the free motion of any number of mutually attracting particles, unrestricted by any of the approximate suppositions required in the treatment of the lunar and planetary theories, is reduced to the simple process of turning a handle. When Faraday had completed the experimental part of a physical problem, and desired that it should thenceforward be treated mathematically, he used irreverently to say—"Hand it over to the calculators." But truth is ever stranger than fiction; and if he had lived until our day he might, with perfect propriety, have said—"Hand it over to the machine."

After referring to the origin of mathematical ideas and their expression, the President passed to the attitude of Literature and Art towards Science; and here he remarked that, considering the severance which still subsists in education and during our early years between Literature and Science, we can hardly wonder if when thrown together in the afterwork of life they should meet as strangers, or if the severe garb, the curious implements, and the strange wares of the latter should seem little attractive when contrasted with the light companionship of the former. The day is yet young, and in the early dawn many things look weird and fantastic which in fuller light prove to be familiar and useful. The outcomings of Science, which at one time have been deemed to be but stumbling-blocks scattered in the way, may ultimately prove stepping-stones which have been carefully laid to form a pathway over difficult places for the children of "sweetness and of light." The instances on which we have dwelt are only a few out of many in which mathematics may be found ruling and governing a variety of subjects. It is as the supreme result of all experience, the framework in which all the varied manifestations of Nature have been set, that our Science has laid claim to be the arbiter of all knowledge. She does not indeed contribute elements of fact, which must be sought elsewhere; but she sifts and regulates them; she proclaims the laws to which they must conform if those elements are to issue in precise results. From the data of a problem she can infallibly extract all possible consequences, whether they be those first sought or others not anticipated; but she can introduce nothing which was not latent in the original statement. Mathematics cannot tell us whether there be or be not limits to time or space; but to her they are both of indefinite extent, and this in a sense which neither affirms nor denies that they are either infinite or finite. Mathematics cannot tell us whether matter be continuous or discrete in its struc-

ture; but to her it is indifferent whether it be one or the other, and her conclusions are independent of either particular hypothesis. Mathematics can tell us nothing of the origin of matter, of its creation or its annihilation; she deals only with it in a state of existence; but within that state its modes of existence may vary from our most elementary conception to our most complex experience. Mathematics can tell us nothing beyond the problems which she specifically undertakes; she will carry them to their limit, but there she stops, and upon the great region beyond she is imperturbably silent.

Conterminous with space and coeval with time is the kingdom of mathematics; within this range her dominion is supreme; otherwise than according to her order nothing can exist; in contradiction to her laws nothing takes place. On her mysterious scroll is to be found, written for those who can read it, that which has been, that which is, and that which is to come. Everything material which is the subject of knowledge has number, order, or position; and these are her first outlines for a sketch of the Universe. If our more feeble hands cannot follow out the details, still her part has been drawn with an unerring pen, and her work cannot be gainsaid. So wide is the range of mathematical science, so indefinitely may it extend beyond our actual powers of manipulation, that at some moments we are inclined to fall down with even more than reverence before her majestic presence. But so strictly limited are her promises and powers, about so much that we might wish to know does she offer no information whatever, that at other moments we are fain to call her results but a vain thing, and to reject them as a stone when we had asked for bread. If one aspect of the subject encourages our hopes, so does the other tend to chasten our desires; and he is perhaps the wisest, and in the long run the happiest among his fellows, who has learnt not only this science, but also the larger lesson which it indirectly teaches—namely, to temper our aspirations to that which is possible, to moderate our desires to that which is attainable, to restrict our hopes to that of which accomplishment, if not immediately practicable, is at least distinctly within the range of conception. That which is at present beyond our ken may, at some period and in some manner as yet unknown to us, fall within our grasp; but our Science teaches us, while ever yearning with Goethe for "Light, more light," to concentrate our attention upon that of which our powers are capable, and contentedly to leave for future experience the

solution of problems to which we can at present say neither yea nor nay. It is within the region thus indicated that knowledge in the true sense of the word is to be sought. Other modes of influence there are in society and in individual life, other forms of energy beside that of intellect. There is the potential energy of sympathy, the actual energy of work; there are the vicissitudes of life, the diversity of circumstance, health, and disease, and all the perplexing issues, whether for good or for evil, of impulse and of passion. But although the book of life cannot at present be read by the light of Science alone, nor the wayfarers be satisfied by the few loaves of knowledge now in our hands, yet it would be difficult to overstate the almost miraculous increase which may be produced by a liberal distribution of what we already have, and by a restriction of our cravings within the limits of possibility. In proportion as method is better than impulse, deliberate purpose than erratic action, the clear glow of sunshine than irregular reflection, and definite utterances than an uncertain sound,—in proportion as knowledge is better than surmise, proof than opinion,—in that proportion will the mathematician value a discrimination between the certain and the uncertain, and a just estimate of the issues which depend upon one motive power or the other. While on the one hand he accords to his neighbours full liberty to regard the unknown in whatever way they are led by the noblest powers that they possess, so on the other he claims an equal right to draw a clear line of demarcation between that which is a matter of knowledge and that which is at all events something else, and to treat the one category as fairly claiming our assent, the other as open to further evidence. And yet, when he sees around him those whose aspirations are so fair, whose impulses so strong, whose receptive faculties so sensitive, as to give objective reality to what is often but a reflex from themselves, or a projected image of their own experience, he will be willing to admit that there are influences which he cannot as yet either fathom or measure, but whose operation he must recognise among the facts of our existence.

MATHEMATICAL AND PHYSICAL SCIENCE. (Section A.)

In the absence of the President (the Rev. Professor Salmon) the Rev. Professor Haughton opened the business of this Section.

Prof. J. D. Everett read the "Report of the Committee on Underground Temperatures." The principal novelty was the proposal to make observations in filled-up bores by a thermo-electric method. Two wires, one of iron and the other of copper, each covered with gutta-percha, were to be joined at both ends, where a portion would be left uncovered. One junction would be buried in the bore, while the other would remain above ground, available for observation. A current would flow through the circuit composed of these two wires whenever the two junctions were at unequal temperatures, and the observer would immerse the accessible junction in a basin of water containing a thermometer, and would regulate the temperature of the water until he found by a galvanometer that no current passed. He would then know that the temperature of the water, as indicated by the thermometer, was the same as that of the buried junction.

The "Report of the Committee for the Determination of the Mechanical Equivalent of Heat" was then read. The Committee are now making a more accurate investigation of the true position of the freezing- and boiling-points of the thermometer when cleared from the effects of the imperfect elasticity of the glass of which they are constructed.

Papers were read by Mr. J. E. H. Gordon, "On some Experiments on Specific Inductive Capacity," and "On the Effect of Variations of Pressure on the Length of Disruptive Discharge in Air."

Mr. G. Johnstone Stoney communicated the results of long investigation, by himself and Prof. J. Emerson Reynolds, "On the Spectrum of Chloro-chromic Anhydride." He described the kinetic theory of gas molecules darting about and continually striking against each other; but, besides these, he said there were internal motions within the molecules, which in many cases were either periodic or quasi-periodic. The evidence of this was obtained from the spectra of gases. For many years he had been engaged in searching for cases of harmonic motion in gas, and, with the assistance of Prof. Reynolds, he had obtained the positions of 105 lines in the spectrum of chloro-chromic anhydride, which proved to be harmonics of one particular motion. The time of one of the oscillations had been measured to the 810,000,000,000th part of a second.

Prof. James Thomson next read a paper "On the Flow of Water in Uniform Régime in Rivers and in Open Chan-

nels generally." He described the various theories which had previously been put forward to account for the well-known fact that the flow of water is not always greatest at the surface, and advanced a new theory, which he illustrated by various diagrams.

This was followed by a paper "On the Pedetic Action of Soap," by Prof. W. Stanley Jevons, which we give *in extenso*:—

Since the publication, in the "Quarterly Journal of Science" for April, 1878, of my paper on Pedesis, or the so-called Brownian movement of microscopic particles, it has been suggested to me that soap would form a good critical substance for experiment in relation to this phenomenon. It is the opinion of Prof. Barrett, and some other physicists, that the movement is due to surface tension, whereas I believe that chemical and electromotive actions can alone explain the long-continued and extraordinary motions exhibited by minute particles of almost all substances under proper conditions. Soap considerably reduces the tension of water in which it is dissolved, without much affecting (as is said) its electric conductibility. If, then, pedesis be due to surface-tension, we should expect the motion to be killed or much lessened when soap is added to water.

Having tried the experiment, I find that the result is of the opposite character to what Prof. Barrett anticipated. With a solution of common soap the pedetic motion becomes considerably more marked than before. I have observed this result not only with china clay and some other silicates, but also with such comparatively inert substances as the red oxide of iron, chalk, and even the heavy powder of barium carbonate. The last-named substance—one of those we should least expect to dance about of its own accord—gave a beautiful exhibition of the movement when mixed with a solution of about 1 per cent of soap, and viewed with a magnifying power of 500 or 1000 diameters.

The correctness of this result was also tested by observing the suspending power of solutions of soap-solution compared with water. If a little china clay be diffused through common impure water—that, for instance, of the London Water Companies—the greater part of the clay will soon be seen to collect together in small flocks, and fall to the bottom in two or three hours, the water being almost clear. However, if a little soap be dissolved in the water, the behaviour

of the clay is quite different. The larger particles soon subside, but the smaller ones remain diffused through the liquid for a long time, giving it a milky appearance, quite different from the flocky and grainy appearance of the common water: if 1 per cent of sodium carbonate be dissolved in common water, and china clay be mixed therewith, the subsidence of the clay is still more rapid, owing, as I have explained, to the increase in the electric conductivity of the fluid, and the consequent decrease of pedesis. But I now find that if soap be added at the same time pedesis is not destroyed, but considerably increased, and the clay remains a long time in suspension, two or three days at least.

These facts give a complete explanation of the detergent power of soap. It has long seemed to me unaccountable that for cleansing purposes the comparatively neutral soap should be better than the alkaline carbonate by itself. We are told that the alkali is but feebly combined with the stearic or other fatty acids. But why combine it at all if we need only the alkaline power of the base? The fact is that the detergent action of soap is due to pedesis, by which minute particles are loosened and diffused through the water, so as to be readily carried off. Pure rain or distilled water has a high cleansing power, because it produces pedesis in a high degree. The hardness of impure water arises from the vast decrease of pedesis due to the salts in solution. Hence the inferior cleansing power of such water. If alkaline salts be dissolved in the water, it becomes capable of acting upon oleaginous matter, but the pedetic power is lessened, not increased. But if soap be added also, we have the advantage both of the alkaline dissolving power and of the pedetic cleansing power. At the same time we have a clear explanation why silicate of soda is now largely used in making soap; for I have shown, in the paper referred to, that silicated soda is one of the few mineral substances which increase the pedetic and suspensive power of water.

I believe that the detergent power of soap and water is one of the many important phenomena which may be explained by the study of pedesis, and I propose to follow up the investigation of this movement in regard to the several substances which tend to increase it.

Mr. Robert Sabine read a paper "On Motions produced by Dilute Acids on some Amalgam Surfaces." These motions result from an alternate play of deoxidation of the mercury underneath the acid by electrolysis, due to the currents of small floating particles of the positive metal

causing the drop to contract, and of oxidation of the surface outside the acid drop causing it to re-expand.

Mr. J. R. Wigham read a paper on "New Applications of Gas for Lighthouses." The first part of his paper referred to the Quadriform Gaslight. Galley Head is a promontory on the coast of Cork, in the neighbourhood of which there had been several shipwrecks. The Commissioners of Irish Lights therefore determined to place upon it the most distinctive and powerful light which they could obtain. With this view, and acting upon the advice of Dr. Tyndall, they adopted the Quadriform Group Flashing Gas Light. The power of the burner was obtained by a peculiar arrangement of numerous fishtail jets, and by suspending over the flame an oxidiser of talc, or some other material, by means of which the current of air was brought in contact with the most smoky part of the flame, rendering it not only smokeless, but exceedingly white. The oxygen of the air was twice availed of; first through the bottom of the flame, and secondly at the top, where its action raised to a white-heat a large quantity of solid carbon found there. The burner requires no chimney-glass. It was so constructed that the lightkeeper could increase the power of the light by five steps, accordingly as the state of the weather might seem to require. In clear weather 28 jets were used, and the number might be enlarged to 48, 68, 88, or 108. The changes from one to another could be very quickly effected by the use of mercurial joints. [The burner which was exhibited on the table was then lighted, and the five different degrees of illuminating power were illustrated, the effect of such an immense volume of flame being most startling in such a confined space.] It was well known that some "fogs" are so dense that even the rays of the sun could but feebly penetrate through them; but when the weather was merely what was called "thick," then it was that the mariner derived great benefit from such differentiating lights. The power of the burner would, of course, be very much increased by the use of lenticular apparatus, a specimen of which was before the meeting. [It may be here parenthetically remarked that early in the day some amusement was caused by the fact that the rays of the sun shining through the lens, which faced the window, set the green baize table-cover smoking, and it had to be placed under cover.] If instead of using this ordinary lighthouse lens, which was designed and calculated to transmit the light of an oil-lamp 4 inches in diameter and 3½ inches high, a lens made to suit his large gas-flame, which was 12 inches in diameter and

8½ inches high, was used, of course the illuminating power would be enormously increased. He trusted that before long lighthouse authorities would sanction the construction of such lenses, and so gain the full benefit of the large flames which gas only could produce. Being fully convinced of the importance of using large lights in illuminating fogs, he determined to use lenses to the utmost limit which was now permitted, and he designed a means by which he was able to quadruple the power of the largest gas-light. This plan consisted in placing two and three and four burners vertically over one another, and making an arrangement by which the products of the combustion of the lower burners were turned outwards, so as not to interfere with the upper burners, while the supply of fresh air was given through cylindrical openings, having no contact with the flues. The illuminating power was thus materially increased. The quadriform apparatus erected at Galley Head contains 32 lenses. As the lenses touch each other the rays of light blend at a short distance, and throw out one bright light. It is calculated that its illuminating power coupled with this large gas-burner was about equal to one million sperm candles. The light at Galley Head is not only quadriform, but is also a group-flashing light—that is, the flashes from the lenses, instead of being simple flashes, were each of them, by the continual extinction and re-ignition of the gas, broken up into four or five beams, which constituted a group of flashes, recurring at regular intervals. This is accomplished by the same clockwork machinery as that by which the lenses were caused to revolve. The interval between the groups and flashes is one minute, and the interval between the flashes two seconds, during which the gas is shut off, and thus there is a great economy of gas.

The second portion of the paper described the combined gas and electric light for lighthouses. For use during fogs Mr. Wigham added an intense light to his large gas-burner, which consists of what he terms a core for his burners. He preferred the electric light because of its greater intensity and the facility with which it could be applied.

The third portion of the paper dealt with a mode of lighting sea beacons from a position on shore. When it is desired to maintain lights on beacons to which access by boats is difficult or expensive, Mr. Wigham advises the application of gas properly dried by chloride of calcium as the means of illumination. The gas station on shore may command any number of beacons, which may be simultaneously lighted. During the daytime the gas was supplied at a

pressure equal to a column of water 6 inches high, to maintain a small jet in the lantern on each beacon. The high pressure prevented the jet from being blown out by the wind, and the arrangement which he had devised enabled the operator to turn on the flame or diminish it to a small jet as easily as the same result could be accomplished in the case of an ordinary light in a dwelling-house, but by using exactly opposite means, *i.e.*, the gas was turned *off* to be lighted and turned *on* to be extinguished.

Mr. Wigham also read a short paper on "Fog Signals." He proposes to use the gas available in lighthouses for gas guns. The report is caused by the explosion of the mixture of oxygen and coal-gas. The gun may be fixed on a rock in the sea at a considerable distance from a lighthouse or a fog-signal station, and will be lighted and fired as often as required from the station, without the keepers leaving their post.

A third paper was read by Mr. Wigham "On a New Atmospheric Gas Machine," which the inventor claimed was admirably adapted for places where coal-gas is difficult of application, as in country houses at a considerable distance from towns. When two burners of the same size were lighted, the one with ordinary gas and the other with atmospheric gas, it was difficult to tell which was the brighter or clearer. Mr. Wigham said it required neither fire nor retorts nor gas-holders; no special knowledge was necessary on the part of the person who attended to it, and the products of its combustion were as harmless as those evolved from the purest wax. It would not tarnish silver or injure the decorations of any furniture.

Mr. G. J. Stoney read a "Report on the Oscillation-Frequencies of the Rays of the Solar Spectrum." The report shows that so long as light is propagated through a vacuum the undulator, however complex, maintains its form unaltered at all distances from the source of light; for in vacuous spaces waves of different periods advance at the same rate and directly forward, and therefore the simple component undulations which are represented by the several terms of a sinusoid series accurately accompany each other throughout their whole journey. But the event is different if the light encountered an optical agent which acted differently on waves of different periods. Of this kind were the prisms and diffraction-gratings of our spectroscopes. Waves of different periods are compelled to travel in different directions, and thus the several terms of the sinusoid series appear under the form of lines in the spectrum. The wave-

lengths corresponding to each position in the spectrum had been determined with great care, and these, when corrected for the dispersion of the air, were proportional to the corresponding periodic times, which thus become known. By a discussion of the observations it might be expected that much will be learned with regard to the original disturbance caused by the source of light. In the present state of science it is of importance to facilitate this inquiry as much as possible, and it is hoped that aid will be given to the student of Nature by the table published in connection with the Report, in which the oscillation-frequencies of the principal rays of the visible part of the solar spectrum have been computed from Angstrom's determinations of their wave-lengths in air, combined with Ketteler's observations on the despersion of air.

Mr. Stoney also read three other papers :—" On a Spectroscope of Unusually Large Aperture," " On the Support of Spheroidal Drops and Allied Phenomena," and " On the Cause of the Travelling of Spheroidal Drops."

Captain Douglas Galton then read a paper " On some Recent Experiments upon the Coefficient of Friction between Surfaces Moving at High Velocities." The author has recently been engaged in making some experiments in connection with the action of brakes in use on railways. A number of diagrams and tables illustrated the means by which the results were obtained, and the principal results shown by them may be summed up as follows :—(1.) The application of brakes to the wheels, when skidding is not produced, does not appear to retard the rapidity of rotation of the wheels. (2.) When the rotation of the wheels falls below that due to the speed at which the train is moving, skidding appears to follow immediately. (3.) The resistance which results from the application of brakes without skidding is greater than that caused by skidded wheels. (4.) During the movement of skidding the retarding force increases to an amount beyond that which prevailed before the skidding took place ; but immediately after the act of skidding is complete, this pressure falls down again to much below what it was before the skidding. (5.) The pressure required to skid the wheels is much higher than that required to hold them skidded, and appears to bear a relation to the weight on the wheels themselves, as well as to their adhesion and velocity. The general conclusion which would appear to follow from the results of the preliminary experiments is that none of the hand brakes, and only some of the continuous brakes now in use, have been designed

with a clear knowledge of the most essential conditions required in a perfect brake.

The Rev. Robert Harley, F.R.S., read a paper "On the Stanhope 'Demonstrator,' or Logical Machine." The author stated that towards the close of the last century a logical instrument was constructed by Charles, third Earl Stanhope. The present Earl found the instrument and some fragmentary papers on Logic among the relics of his scientific ancestors, and, at the suggestion of Mr. Spottiswoode, placed them in the hands of Mr. Harley, who has made a careful study of them. Earl Stanhope (born 1753, died 1815) is known to Science chiefly by his printing-press, microscopic lens, arithmetical machine, monochord, and steamboat; but of his logical speculations, which occupied his thoughts for thirty years, and of his curious contrivance for working logical problems, called by him the "Demonstrator," nothing has been known. Mr. Harley noticed that Stanhope anticipated George Bentham, Sir William Hamilton, George Boole, and others, in his quantification of the predicate, and notably De Morgan's rule for the numerically definite syllogism. Stanhope stated the rule as applicable to all syllogistic reasoning, and he constructed his "Demonstrator" for the mechanical working of the rule. It does not seem equal to very difficult and complicated questions, nor nearly so powerful as Prof. Jevons's logical machine, which before the discovery of the "Demonstrator" was supposed to be the first invention in this direction.

Dr. Janssen described his method of Solar Photography, and read a paper "On Total Eclipses."

Mr. E. J. Hardman read a paper "On Lead and Platinised Lead as a Substitute for Carbon and Platinised Silver in Leclanché, Bichromate, and Smee's Batteries."

Mr. W. J. Millar described a new Receiver for Microphone.

Mr. Mattieu Williams read a paper "On an Experimental Verification of the Velocity of Transmission of Radiant Heat."

The "Report of the Committee on Atmospheric Electricity" was read by Prof. Forbes. Three electrometers have been given: one to Surgeon-Major Johnson, in India; the second to Mr. Michie Smith, in India; and the third to Dr. Grabham, in Madeira. Surgeon-Major Johnson was engaged in the frontier war in India; and Dr. Grabham has hitherto been too much occupied to make observations; while Mr. Michie Smith has not yet had time to furnish any;

so that up to the present time no observations have been received.

Mr. W. Ladd read a paper "On Edmunds's Phonoscope." This instrument is for producing figures of light from vibrations of sound. It consists essentially of three parts—an induction coil, an interrupter, and a rotary vacuum tube. The action of the instrument is as follows:—Sounds from the voice or other sources produce vibrations on the diaphragm of the interrupter, which, being in the primary circuit of the induction coil, induce at each interruption a current in the secondary coil, similar to the action of a contact-breaker or rheotome; therefore each vibration is made visible as a flash in the vacuum tube. The tube revolving all the time at a constant speed, the flashes produce a symmetrical figure like the spokes of a wheel, as in the Gassiot star. The number of spokes or radii is according to the number of vibrations in the interrupter during a revolution of the tube, and the number of vibrations being varied to any extent according to the sounds produced, the figures in the revolving tube will be varied accordingly. The same sounds always produce the same figures, provided the revolutions be constant. In case of rhythmical interruption being produced in a given sound, as in a trill, most beautiful effects are noticeable, owing to the omission of certain radii in regular positions in the figure. The uses of this instrument are the rendering visible of sounds, and showing the vibrations required in their production, and it forms a mode of confirming by sight an appeal to the ear.

The next paper was by the same author, "On Byrne's Compound Plate Battery," described in the last number of the "Quarterly Journal of Science."

Prof. G. Forbes described "A Clock with a Detached Train." In the course of some experiments still progressing he used a clock to give electric signals every second. It has a train of only one wheel working in a pinion. It is driven by a weight which falls through 5 feet in an hour. This clock only goes one hour, but serves the purpose for which it was made. He wished lately, however, to make it go for a longer time, so he drove it by a weight hung by a pulley on an endless chain in the usual way, and he attached a common five shilling Swiss alarm clock to the chain to wind it up continuously. This answers so well that he would suggest a similar construction as not only the cheapest, but also the best form of a clock with escapement. It consists of a pendulum and escapement with no train whatever, with

an endless chain or thread passing over a pulley on the axles of the scape-wheel, and over the minute wheel of a secondary clock, hanging between them in a festoon which supports the weight by a pulley. The secondary clock gives the hours and minutes, and the clock without train shows the seconds. We thus have a clock without the errors introduced by a train. It is a gravity escapement without the locking friction.

Prof. G. Forbes also described "An Instrument for Determining the Quantity of Fire-Damp in Mines," which consists of a resonator of various dimensions, and a tuning-fork of definite pitch. The resonator is a metal tube 1 inch in diameter and 15 inches long, in which a piston slides so as to regulate the length of the tube. This tube is fixed in a block of wood, to which is attached a tuning-fork, whose points are just above the open end of the tube. The tuning-fork is sounded in every convenient way, and the piston is moved out and in until the proper length is found, which is indicated by the resonator intensifying the sound of the tuning-fork. With practice the length can thus be determined with an accuracy of at least 1 in 250. But the length depends on the density of the gas, a light gas requiring a longer resonator, and, by reading off on a scale the position of the piston, a person can judge of its density. In this manner 1 or 2 per cent of fire-damp, mixed with common air, can be detected. Barometric pressure produces no difference on the instrument. The temperature correction is made by reading off a thermometer of the proper dimensions, instead of reading off a fixed mark on the piston.

Prof. Silvanus P. Thompson narrated several instances of rainbows, chiefly seen in Switzerland, when radial streaks of light, devoid of colour, were observed within the primary bow, and without the secondary bow.

Mr. C. Meldrum read a paper "On Sun-Spots and Rainfall." The conclusion at which the author arrived, from a great number of observations in all parts of the world, was that the maximum and minimum rainfall apparently coincided with the maximum and minimum sun-spots respectively.

Mr. W. Morris read a paper "On the Temperature of the Earth Within." He held that the present method of determining underground temperatures with the thermometer as used in air or water was quite unsatisfactory. He suggested the employment of pairs of chronometers, one of each pair to be placed at the bottom of a bore, and the other at the surface.

Mr. James Glaisher read the "Report of the Committee on Luminous Meteors." It contained an account of meteors doubly observed, with a table showing their real paths, velocities, and radiant points; a detailed account of large meteors; general directions to observers for recording meteors and aërolites; the discussion of a meteor of short period, and an analysis of the constituents of masses of meteoric iron and stone-falls.

Lord Rosse gave a short explanation of the peculiarities of an equatorial mounting recently erected at Parsonstown, showing the points in which it differed from the ordinary type of mounting. The optical arrangements were exactly the same as in ordinary cases. The old mounting at Parsonstown, being made of wood, fell into decay, and he resolved to replace it by metal, and mount the instrument equatorially. The leading peculiarities of the mounting were, that the points of reversal were situated at the east and west, instead of at the north and south. The bearings on which the instrument turned in right ascension were smaller than in the ordinary mountings. The motions in declination and in right ascension were effected by means of screws, so that on a windy night the instrument could not run away with the observer. The tube was square. The clock was connected by means of a stretched strap of brass, and the gallery was quite unique. The counterpoise was less than usual. The only reflector of a similar size mounted equatorially was that constructed by Mr. Grubb for the Melbourne Government; but its drawback was that just as the observer had moved it to the very best position for observation—namely, the south—it had to be reversed and every connection altered. The gallery was also worked by means of screws, so that there was no danger of the observer coming down quicker than he wished. The tube was square in section. The cage was independent of the mounting, moving on a circular rail, and with a second motion like that of a derrick crane. The mounting was only suitable for a reflecting telescope.

Prof. R. S. Ball read a paper "On the Annual Researches made at Dunsink on Parallax of Stars." Before commencing the observations described and tabulated in the paper a working list was formed, containing red stars, variable stars, stars with large proper motions, and several other stars which were chosen on different grounds. The observations had the special object of seeing whether any of them had a large parallax. Forty-two different objects had been selected from this working list, but in almost every

case the observations convinced him that the parallax was constantly less than one second, and most probably did not exceed half a second. It would therefore be understood that the results were purely negative so far as the immediate object in view was concerned, as they did not suggest the existence of any parallax worth following up. The principle upon which the reconnoitring observations were conducted was this—the effect of annual parallax upon a star was to make the apparent place of the star describe a minute ellipse, of which the mean place of the star occupied the centre. The star was observed twice. At the first observation the star was at or near one of the extremities of the major axis of the ellipse; at the second observation it was at the other extremity—so that the observations were so arranged that in each case parallax would have the greatest effect it was capable of producing.

Prof. H. Hennessy read a paper "On the Climate of the British Islands." When he first made his investigations on this subject he was led to the conclusion that the distribution would be represented by isothermal lines having a certain parallelism to the coast line of these islands. These isothermal lines had been laid down from actual observation, because he had found that the law of increase and decrease of temperature, in going inland over a table land or flat country, was so extremely slow that it was perfectly absurd to use the co-efficient of one degree to 300 feet, which had been obtained by balloons. The actual results confirmed in the minutest particulars the theory of isothermal lines which he propounded years ago, and he believed that the more observations were multiplied not only in these islands, but in New Zealand, Tasmania, and similar places, the more would it be found that his theory was correct. The islands, however, must have their coasts bathed by oceanic currents of a high temperature. The isothermal lines for Ireland showed that the distribution of temperature was more influenced by the sea than by latitude.

Other papers read were "On a Diagonal Eyepiece, required in certain Optical Experiments," by Prof. G. Forbes; "On New Magnetic Figures," by Dr. S. P. Thompson; "On Dimensional Equations," by Prof. James Thomson; "On a New Form of Electro-Registering Apparatus," and "On an Isochronous Pendulum," by Mr. Denny Lane; "On the Variability of Standard of Height," by Mr. J. E. Hilgard; and "On Lightning Conductors," by Mr. R. Anderson.

The Committee's "Report on Babbage's Analytical Engine" was read in the department of Mathematics. After referring to the general principles of calculating engines, and the special characteristics and capabilities of Mr. Babbage's, the Report dealt with the advisability of constructing an analytical machine. On the question of cost the Committee said—"It has not been possible for us to form any exact conclusion as to the cost. Nevertheless there are some data in existence which appear to fix a lower limit to the cost. Mr. Babbage, in his published papers, talks of having 1000 columns of wheels, each containing fifty distinct wheels: this apparently refers to his store. Besides the many thousand moulded pewter wheels for these, and the axes on which they are mounted, there is the mill, also consisting of a series of columns of wheels and of a vast machinery of cams, clutches, and cranks, for their control and connection, so as to bring them within the directing power of the Jacquard systems of variable cards and operation cards. Without attempting any exact estimate, we may say that it would surprise us very much if it were found possible to obtain tenders for less than £10,000, while it would pretty certainly cost a considerable sum to put the design in a fit state for obtaining tenders. On the other hand, it would not surprise us if the cost were to reach three or four times the amount above suggested. It is understood that towards the close of his life Mr. Babbage had contemplated carrying out the manufacture of the engine on a smaller scale, confining himself to twenty-five figures instead of fifty, and to two hundred columns instead of a thousand or more. This would, of course, reduce the expense of the metal work proportionately, but we do not think that it would materially reduce the charge which we anticipate for bringing the design into working order." The conclusion at which the Committee arrived was that they could not advise the British Association to take any steps to procure the construction of Mr. Babbage's analytical engine.

In the department of Physical Science Mr. J. T. Bottomley read the "Report of the Committee for commencing Secular Experiments on the Elasticity of Wires." The arrangements for suspending the wires are complete, and two wires, one of palladium and the other of platinum, have been suspended in their places.

Prof. Adams exhibited and described a new form of polariscope which enabled measurements to be made of crystals

to the diameter of rings, and also the angles between the optic axes.

A telegram and letter from Prof. W. C. Ayrton, of Japan, to Sir Wm. Thomson, "On a New Determination of the Number of Electro-static Units in the Electro-magnetic Unit," were read. The letter gave an account of very interesting and delicate experiments, which resulted in an answer of 298,000,000 metres per second, corresponding with the velocity of light as given by Foucault.

Mr. R. J. Moss gave a description of an instrument of research for the investigation of Crookes's stress and experiments on spheroidal drops.

Prof. Barrett described a new form of trap-door electrometer.

Mr. J. E. Gordon described some experiments on specific inductive capacity. His observations were illustrated by formulæ and coloured diagrams, without which they cannot be well understood.

At the request of the Chairman, Prof. W. E. Ayrton, who had just arrived from Japan, said—The value of Mr. Gordon's experiments arises from his belief that the specific inductive capacity of a dialectric rapidly increases with time. As Mr. Gordon has remarked, Prof. Perry and myself were theoretically led to this idea several years ago, as we described in our paper on the "Viscosity of Dielectrics" some time back, and which appears in a recent number of the "Proceedings of the Royal Society of London." The idea that all dialectrics behave more or less like strained viscous substances has been the leading principle that has guided Prof. Perry and myself in our electrical observations—an idea to which our attention has been especially directed in the following way:—When Mr. Perry was examining certain curves obtained for the time increase of strain in a substance subjected to a constant stress simultaneously with some that we had obtained for the soaking out of the charge in an excellently well-insulated Leyden jar, the coatings of which had been maintained for days at a constant difference of potentials, then suddenly discharged, and finally insulated the one from the other, he observed a remarkable analogy between the two classes of curves, and careful examination of all our results up to the present time bears so close an analogy with the stress and strain phenomena in various substances, that we feel that this analogy means a physical connection. Reasoning by analogy, we may conclude that as the rate of production of electric strain grows less and less as the in-

terval elapsing since charging increases, therefore the rate of conversion of electric energy into heat, that is, conduction, also grows less and less, and therefore it is correct to say that the resistance of a dielectric does really increase by electrification. Besides this there is, of course, some of the absorbed energy which is recoverable, and which, therefore, must not be confounded with conduction; just as the energy recoverable from a deflected beam must be distinguished from that lost through conversion into heat, on account of internal friction. From the curves we have obtained of the charging of condensers, and assuming that there is no discontinuity, we must assume that even the first charging is itself a very rapid absorption, and since there is viscosity, even the very first charging must be accompanied with a generation of heat—that is, true conduction. Also, since it is known that gases, like all other substances, are to a certain extent viscous, we cannot believe that air and other gaseous condensers show absolutely no absorptive phenomena; in fact, sufficiently accurate experiments have not yet been made on the subject. We conclude, therefore, that the less the specific resistance the greater is its molecular plasticity, and the more plastic the substance is the greater will be the first charge; therefore from the stress and strain analogy it follows that the less the specific resistance of a substance the greater will generally be the specific inductive capacity. Influenced by these ideas we examined experimentally the specific resistance ofseveral dielectrics, and were eventually able to compare the specific inductive capacities and specific resistances of dilute sulphuric acid, mica, gutta-percha, shellac, Hooper's material, ebonite, paraffin-wax, glass, air, and we found that if the above substances were arranged in descending order of specific inductive capacity they were found arranged in ascending order of specific resistance. Again, since the resistance of air to electric discharge is less than that of a Sprengel vacuum, we were theoretically led to expect (in contradiction to the results of Faraday, who concluded that the specific inductive capacities of all gases at temperatures and pressures were identical) that very accurate experiments would show that different gases had different specific inductive capacities. This result we were experimentally able to verify after months of investigation, and we found that the denser the gas the higher the specific inductive capacity, a vacuum having the least capacity of the substances we experimented on. It was our intention at that time to determine accurately the electric capacity of a Crookes's vacuum, an investigation I hope to complete

this winter, and I anticipate finding this capacity extremely small; for although we found that the specific inductive capacity of a moderately good vacuum made in a space originally containing air was as much as nine-tenths of that of air at ordinary pressure, still Mr. Crookes's recent experiments connected with his radiometer on the logarithmic decrement of a torsion pendulum vibrating in gaseous or vacuous spaces show that the viscosity of the gas does not much diminish until the vacuum has become very perfect. Consequently, it may be anticipated that it will be at the completion of the exhaustion (with a most perfect Sprengel pump) of a gas condenser that the great diminution in the specific inductive capacity of the vacuous dielectric will be experienced. If this result be really arrived at, then it will follow that if it were possible to insulate a conducting wire in a vacuum tube under the sea, the speed of telegraph messages through a long submarine cable, such as crosses the Atlantic or Indian Oceans, could be raised from the present low speed of seventeen words a minute to that of one thousand, which has already been obtained on land lines with Bain's automatic instruments. I may also mention that the mathematical reduction of the curves of viscores yielding, soaking out of charge in dielectrics, &c., will form the subject of a paper Mr. Perry and I propose publishing very shortly.

Chemical Science. (Section B.)

The President, Professor Maxwell Simpson, F.R.S., in delivering the opening address, brought before the section the claims of chemical science to a place in general education, and the claims of original research to a place in the curriculum for higher degrees in our universities.

Without chemistry, he said, we can know nothing of the air we breathe, the water we drink, or the food we eat; we cannot understand the process of combustion, respiration, fermentation, putrefaction, or the endless chemical changes which are continually in operation around us, and which affect our lives for good or for evil. The whole of the phenomena of nature must for ever remain to us, more or less, an inscrutable mystery. Was it not also desirable that we should have some acquaintance with the chemical arts from which we derive so many of our comforts and luxuries: Should we not know something of the arts of photography, dyeing, metallurgy—something of the manufacture of glass and china, and of the thousand beautiful things that are

constantly in our hands? Chemistry, too, furnishes us with a key which enables us to unlock vast stores of knowledge contained in physics, geology, mineralogy, physiology, and astronomy.

With regard to the mental discipline, the mind of the student is, continued Professor Simpson, exercised in both the inductive and deductive methods of reasoning. His original faculties are stimulated by the consciousness that he can in many cases readily test the worth of his ideas by experiment. With inexpensive apparatus and a good balance, the intelligent student can make out for himself some of the laws and many of the facts of science, and, it may be, also add to them. He glides insensibly from the known to the unknown. The student of chemistry can reach the field of original work sooner than the student of most other sciences. Once he commences original research the development of his intellectual faculties rapidly progresses. His imagination is daily exercised in propounding new theories, and devising experiments in order to ascertain their truth or falsehood. Laboratory work teaches us to use our senses aright, sharpens our powers of observation, and prevents us from reasoning rashly from appearances. It also promotes manual dexterity, and trains the hands to work in subordination to the head. With regard to the effect of original work on the character, many virtues were necessary to the chemist—courage, resolution, truthfulness, and patience. He is often obliged to perform experiments which are attended with great danger. But the chemist must not be discouraged by fear of accident, neither must he be disheartened by the temporary failure of his experiments, nor at the slowness of his processes. Bunsen was obliged to evaporate 44 tons of the waters of the Durcheim springs in order to obtain 200 grains of his new metal cæsium. It took Berthelot several months to form, by a series of synthetical operations, an appreciable quantity of alcohol from water and carbon, derived from carbonate of baryta. Many years ago, in the laboratory of Wurtz, a poor student was carrying from one room to another a glass globe which contained the product of a month's continuous labour, when the bottom of the globe fell out, and the contents were lost. Nothing daunted, he recommenced his month's work, and brought his research to a successful issue. Above all things the chemist must be true. He must not allow his wishes to bias his judgment or prevent him from seeing his researches in their true light.

He was glad that the importance of original research, as

a part of higher education, is at last beginning to be recognised in this country. The Royal University Commission at Oxford has recently recommended that candidates for the higher degrees in science shall, in that University, be required in future to work out an original investigation. In Germany, where education has been so long and so well understood, original work has been, for at least the last half century, a *sine quâ non* for a degree. Another admirable rule exists in that country, the adoption of which in Great Britain might go far to wash out the stain from our islands, of not having contributed our fair quota to the advancement of human knowledge. It is this—the Germans make a point of securing invariably that their scientific chairs shall be filled by men who have already distinguished themselves by their discoveries. The professor, on his appointment, naturally desires to continue his investigations, and endeavours to secure, and usually succeeds in securing, the assistance of his pupils. This is a mutual advantage. The professor is able to do more work for science, and the student, on his part, learns to conduct for himself an original investigation. Hence there is always a rising generation of original workers in Germany who turn out papers more or less meritorious with the rapidity of a Walter's press. They are stimulated by the hope of one day arriving themselves at a professor's chair, the path to which they are well assured is only through the toilsome field of original investigation. The labour is also one of love, and the student's ambition, for the time at least, is bounded by the desire to do something for science. And from a multitude of such enthusiasts the great professors come.

Speaking of the encouragement of research in this country the President said, that to promote original work in this country, he believed it was indispensable that our professors should be well paid. It would save them from the necessity of supplementing their incomes by commercial analyses, and thus enable them to devote their spare time to original work. And to secure that they shall have spare time, he would like to see in every laboratory a competent assistant, who would be able occasionally to take up the professor's lectures, should he be engaged in important work. He was glad to see that the Oxford Commission also recommends the appointment of well-paid assistants. Well-paid professorships and well-paid assistantships would be attractive prizes for our students to work up to; and if it were clearly understood that the only way to these prizes was through

original investigation, we should very soon have an army of zealous and competent workers. The plan of appointing a staff of original workers unconnected with teaching had been proposed; but he did not approve of it. The original worker is, as a rule, the best teacher, and the rising generation of students should not be deprived of the advantage of this instruction. No doubt the Government Grant Fund did a good deal for science, but the field of its operations is, under present conditions, limited. Professors, as a rule, are so occupied with teaching that they cannot avail themselves of the fund; and of those students who might be competent and willing, very few can afford to do so. Instead of trusting to the precarious and insufficient support of the fund, they must endeavour to settle themselves permanently in life. It was much to be regretted that the Universities of Oxford and Cambridge, with such splendid revenues at their disposal, should contribute so little to the advancement of physical science. He hoped the day was not far distant when the fellowships—or at least a few of them—which now go to reward young men for merely passing a good examination, shall be given *without examination* to men who shall have advanced human knowledge in any department. At present a fellowship of £250 or £300 a-year, lasting ten or twelve years, and in some cases for life, may be obtained on showing proof of a good memory—or, at most, a capacity for assimilating other men's ideas. To make discoveries—to follow out a new train of thought, and establish it by experiments specially devised to that end, has been left not only without reward, but almost without recognition in our two principal seats of learning. The world at large, ignorant as it is, has a sounder instinct on this subject, and the man who makes the humblest addition to the stock of knowledge in the world rarely fails to receive the world's respect and honour. Professor Simpson concluded by saying that these suggestions could not be well carried out unless the Government takes into its own hands the appointment to all scientific chairs. Of this he thought he saw indications. He believed that sooner or later the Government will assume the supreme direction of education in this country. It has already taken primary education under its control, and quite recently, in Ireland, intermediate education to a great extent. And did the appointment of so many University Commissions not show a disposition on the part of the Government to assume the direction of higher education also?

Geology. (Section C.)

In opening the proceedings of this section the President (Dr. Evans) called attention to the fact that the present was the third occasion on which the British Association had met in this city; its first meeting was held in Dublin in the year 1835. The President of the Geological Section being a man of whom Irish science might well be proud, and who, he was thankful to say, was still living to enjoy his well-deserved honours—the veteran geologist, Sir Richard John Griffith, the author of the first Geological Map of Ireland. It seemed hardly credible that the construction of this map was commenced in the summer of 1812, or sixty-six years ago; but the records of the Geological Society of London testify to the still more remarkable fact that Sir Richard Griffith was elected a Fellow of that society in 1808—seventy years ago. Indeed, in 1854, when the Wollaston medal was awarded to the then Dr. Griffith, the president, the late Professor Edward Forbes, spoke, as he said, reverentially to one of the earliest members of the society, and to a geologist who appeared in print before he, the president, was born. It was well said on that occasion that the map lately mentioned was one of the most remarkable geological maps ever produced by a single geologist.

(Our readers will have heard with regret of the death of Sir Richard Griffith only about a month after the delivery of Dr. Evans's address. He died on the 22nd of September at the advanced age of 94.) Dr. Evans also paid a tribute of respect to the memory of one who was originally a student in Trinity College, and who subsequently occupied posts of the highest importance in connection with the Geological Society of Dublin and the Geological Survey of Ireland, besides filling the professorial chair of geology in the Dublin University, to Dr. Thomas Oldham, the late director of the Geological Survey of India.

The president then referred to the geology of Ireland, and passed on to the consideration of the date which is to be assigned to the implement-bearing beds of Palæolithic age in England. Dr. James Geikie has, he said, held that, for the most part, they belong to an interglacial episode towards the close of the glacial period, and regards it as certain that no palæolithic bed can be shown to belong to a more recent date than the mild era that preceded the last great submergence.

His follower, Mr. Skertchley, records the finding of palæolithic implements in no less than three interglacial beds,

each underlying boulder clays of different ages and somewhat different characters, the Hessle, the purple, and chalky boulder clay. This raises two main questions; first, as to how far Dr. Croll's theory of the great alternations of climate during the glacial period can be safely maintained; and secondly, how far the observations as to the discovery of implements in the so-called Brandon beds underlying the chalky boulder clay can be substantiated. Another question is how far the palæolithic deposits can be divided into those of modern and ancient valleys, separated from each other by the purple boulder clay, and the later of the two older than the Hessle beds. He would only observe, that in a considerable number of cases the gravels containing the implements can be distinctly shown to be of much later date than the chalky boulder clay, and that if the implements occur in successive beds in the same district, each separated from the other by an enormous lapse of time, during which the whole country was buried beneath incredibly large masses of invading ice, and the whole mammalian fauna was driven away, it was a very remarkable circumstance. It was not the less remarkable because this succession of different palæolithic ages seemed to be observable in one small district only, and there was as close a resemblance between the instruments of the presumedly different ages as there was between those of admittedly the same date. He had always maintained the probability of evidence being found of the existence of man at an earlier period than that of the post-glacial or quaternary river gravels, but, as in all other cases, it appeared to him desirable that the evidence brought forward should be thoroughly sifted and all probability of misapprehension removed before it was finally accepted. In the present state of our knowledge, he did not feel confident that the evidence as to these three successive palæolithic deposits had arrived at this satisfactory stage. At the same time it must be borne in mind that if we make the palæolithic period to embrace not only the river gravels but the cave deposits of which the south of France furnishes such typical examples, its duration must have been of vast extent.

In connection with the question of glacial and inter-glacial periods, Dr. Evans mentioned that of climatal changes in general. The return of the Arctic Expedition, and the reports of the geological observations made during its progress, which have been published by Captain Fielden, one of the naturalists to the expedition, in conjunction with Mr. De Rance and Professor Heer, have conferred additional interest on the

question of possible changes in the position of the poles of the earth, and on other kindred speculations. Near Discovery Harbour, about latitude 81° 40′, Miocene beds were found containing a flora somewhat differing from that which was already known to exist within the Arctic regions. "The Grinnell Land lignite," say the authors of the report, "indicates a thick peat moss, with probably a small lake, with water lilies on the surface of the water and reeds on the edges, with birches, poplars, and taxodiums on the banks, and with pines, firs, spruce, elms, and hazel-bushes on the neighbouring hills." When we consider, continued Dr. Evans, that all of the genera here represented have their present limits at least from twelve to fifteen degrees farther south, while the taxodium is now confined to Mexico and the south of the United States, such a sylvan landscape as that described seems entirely out of place in a district within six hundred miles of the pole, to which indeed, if land then extended so far, these Arctic forests must have also extended in Miocene times. Making all allowance for the possibility of the habits of such plants being so changed that they could subsist without sunlight during six months of a winter of even longer duration, he could not see how so high a temperature as that which appears necessary, especially for the evergreen varieties, could have been maintained, assuming that Grinnell Land was then as close to the North Pole as it is at the present day. Nor is this difficulty decreased when we look back to formations earlier than the Miocene, for the flora of the secondary and palæozoic rocks of the Arctic regions is identical in character with that of the same rocks when occurring twenty or thirty degrees farther south, while the corals, encrinites, and cephalopods of the carboniferous limestone are such as, from all analogy, might be supposed to indicate a warm climate.

The general opinion of physicists as to the possibility of a change in the position of the earth's axis has, continued the president, recently undergone modifications somewhat analogous in character to those which, in the opinion of some geologists, the position of the axis has itself undergone. Instead of a fixed dogma as to the impossibility of change, we find a divergence of mathematical opinion and variations of the pole differing in extent, allowed by different mathematicians who have of late gone into the question. All agree in the theoretical possibility of a change in the geographical position of the earth's axis of rotation being affected by a redistribution of matter on the surface, but they do not

appear to be all in accord as to the extent of such changes. Mr. Twisden, for instance, arrives at the conclusion that the elevation of a belt twenty degrees in width, such as that which he (the president) suggested in his presidential address to the Geological Society in 1876, would displace the axis by about ten miles only, while Professor Haughton maintains that the elevation of two such continents as Europe and Asia would displace it by about sixty-nine miles, and Sir W. Thomson has not only admitted, but asserted as highly probable, that the poles may have been in ancient times "very far from their present geographical position, and may have gradually shifted through ten, twenty, thirty, forty, or more degrees without at any time any perceptible sudden disturbance of either land or water."

The President was glad to think that this question, to which he had to some extent assisted to direct attention, had been so fully discussed, but he could hardly regard its discussion as being now finally closed. It appeared to him doubtful whether eventually it would be found possible to concede to this globe that amount of solidity and rigidity which at present it is held to possess, and which to his mind at all events seemed to be in entire disaccordance with many geological phenomena. Yet this, as the Rev. O. Fisher has remarked, is presupposed in all the numerical calculations which have been made. He was also doubtful whether in the calculations which have been made, sufficient regard has been shown to the fact that a great part of the exterior of our spheroidal globe consists of fluid which, though of course connected with the more solid part of the globe by gravity, is readily capable of readjusting itself upon its surface, and may, to a great extent, be left out of the account in considering what changes might arise from the disturbance of the equilibrium of the irregular spherical or spheroidal body which it partially covers. It appeared to him also possible that some disturbances of equilibrium may take place in a mysterious manner by the redistribution of matter or otherwise in the interior of the globe. Captain F. J. Evans, arguing from the changes now going on in terrestrial magnetism, has suggested the possibility of some secular changes being due to internal, and not to external causes; and if it be really true that there is a difference between the longest and shortest equatorial radii of the earth, amounting to six thousand three hundred and seventy-eight feet, such a fact would appear to point to a great want of homogeneity in the interior of our planet, and might suggest a possible cause for some disturbance of equilibrium.

Professor Haughton had been mentioned among those who, from mathematical considerations, have arrived at the conclusion that a geographical change in the position of the axis of rotation of the earth is not only possible but probable. In a recent paper, however, he has maintained that, notwithstanding this possibility or probability, we can demonstrate that the pole has not sensibly changed its position during geological periods. He arrives at this conclusion by pointing out that in the Parry Islands, Alaska and Spitzbergen, there are triassic and jurassic deposits of much the same tropical character, and then by a geometrical method fixing the North Pole somewhere near Pekin, and the South Pole in Patagonia, within seven hundred miles of a spot where jurassic ammonites occur, shows that such a theory is untenable. In the same way he fixes the pole in Miocene times near Yakutsk, within eight hundred miles of certain Miocene coal beds of the Japanese islands. These objections were at first sight startling, but he (Dr. Evans) thought it would be found that if, instead of drawing great circles through certain points, we regard those points as merely isolated localities in a belt of considerable width, there is no need of fixing the pole of either the jurassic or the miocene period with that amount of nicety with which Professor Haughton has ascertained its position. The belt may indeed be made to contain the very places on which the objection is founded. One other consideration to be urged was as to the safety of regarding all deposits of one geological period as contemporaneous in time. Although an almost identical flora may be discovered in two widely-separated beds, it appeared to him that chronologically they are more probably of different ages than absolutely contemporaneous; and, inasmuch as the duration of the miocene period must have been enormous, there would be time—if once we assume a wandering of the poles—for such wandering to have been considerable between the beginning and end of the period.

The president then adverted to the discovery of palæozoic rocks under London. So long ago as 1856 the Kentish Town boring had shown that immediately below the Gault red and variegated sandstones and clays occurred, which Professor Prestwich regarded as probably of old red or Devonian age. The boring of Messrs. Meux and Co. has now shown that under Tottenham Court Road, at a depth of little more than nine hundred feet from the surface, there are true Devonian beds, with characteristic fossils, and that Mr. Godwin Austen's prophecy of the existence of palæozoic

rocks at an accessible depth under London has proved true. Professor Prestwich, from a consideration of the French and Belgian coal fields, inclines to the belief that in the district north of London carboniferous strata may be found.

In the department of theoretical geology, the president called attention to some experiments by M. Daubrée, in which he has attempted to reproduce on a small scale various geological phenomena, such as faulting, cleavage, jointing, and the elevation of mountain chains.

With regard to recent progress in palæontology, he referred to the magnificent discoveries in North America, which are principally due to the researches of Professors Marsh, Leidy, and Cope. The *diceratherium*, a rhinoceros with two horns placed transversely, and the *dinoceras*, somewhat allied to the elephant, but with six horns, arranged in pairs, were, he said, as marvellous as some of the beasts seen by Sir John Maundeville on his travels, or heard of by Pliny. But perhaps the most remarkable series of remains ever discovered were those which so completely link the existing horse with the *eohippus* and *orohippus*, and still farther extend the pedigree of the genus *equus*, which had already been some years ago so ably traced by Professor Huxley.

Of these American discoveries, as well as those made in the tertiary beds of Europe, M. Albert Gaudry has largely availed himself in his recent beautiful volume on the links in the animal world in geological times, a work which will long be a text-book on the inter-relation of different orders, genera, and species.

The president concluded by remarking that Professor Marsh has largely added to our knowledge of early forms of birds with teeth. The tertiary *Odontopteryx toliapicus* from Sheppey, described by Professor Owen, seems rather to be endowed with bony tooth-like processes in the jaw, than actual teeth, and the head of the *argillornis* from the same locality is at present unknown. But the *hesperornis* and *ichthyornis* from the cretaceous beds of America possess veritable teeth, in the one case set in a long groove in the jaw, and in the other in actual sockets. Such intermediate, or, as Professor Huxley would term them, intercalary forms, tend materially to bridge over the gap which at first sight appears to exist between reptiles and birds, but which to many palæontologists was far from being impassable, long before the discoveries just mentioned. The amphicœlous character of the vertebræ of *ichthyornis* presents another most remarkable peculiarity, which is also of high signific-

ance. There were rumours of the discovery of another *archæopteryx* in the Solenhofen Slates, which is said to present the head in a much more complete condition than that in which it occurs on the magnificent slab now in the British Museum. As yet, the jaws have not had the matrix removed from them; but should they prove to be armed with teeth, it would to him be a cause of satisfaction rather than surprise, as an opinion he expressed some fifteen years ago, would be confirmed, viz.: that this remarkable creature may have been endowed with teeth, either in lieu of or combined with the beak.

Professor Hull, F.R.S., then proceeded to give a sketch of the geology of the environs of Dublin.

Mr. J. Nolan, M.R.I.A., read a paper "On the Ancient Volcanic Districts of Slieve Gullion, between Dundalk and Carlingford Bays."

Mr. Mattieu Williams, F.R.A.S., F.C.S., read some valuable notes "On the Glaciation of Ireland and the Tradition of Lough Lurgan." The first part of this paper discussed the origin of the ridges of drift which cover so large an area of Ireland, and the fact that this, like all the other varieties of till or boulder clay, are unrepresented by the moraines of existing Alpine glaciers, which have no such clayey matrix; while, on the other hand, true moraines, such as we now see in the course of formation, are the rarest of all the vestiges of ancient glaciation. The author's explanation of this is that the ancient glaciers of Ireland, Scotland, Norway, &c., for the most part terminated in the sea, and deposited the *whole* of their contents in still water as their terminal portions thinned and floated upwards; these deposits thus including the stony material of modern alpine moraines *plus* the fine particles that are washed out by the glacier torrent and now deposited lower down as alluvium. The heaping into ridges he explained by the fluctuations of advance and recession of the glaciers at a later period. (These views are also described in the "Quarterly Journal of Science," April, 1877.)

The second part of the paper refers to an ancient legend, which describes a great fresh water lake occupying the site of Galway Bay, and the formation of the present bay by irruption of the sea through the ancient barriers of the lake. The author met with this legend very recently, and his recollections of the great drift ridges running towards the bay suggested the probability of their former extension across. To verify this he revisited the bay, re-examined

these ridges of drift, and found that several now stand in the Bay, forming long islands and promontories projecting from various parts of its shores, and that some have been cut off by the sea forming cliffs of light coloured boulder clay richly studded with finely striated boulders (specimens and heel-ball rubbings of which were shown). The details of the position of these ridges, and relations of the cliffs (some of which are 50 feet high) to those on the opposite shores are explained.

The soundings between these are also referred to, as they show the existence of great bars connecting some of the most remarkable of these cliff sections of drift.

The author concludes that there is evidence of the former existence of several ridges of drift extending obliquely into the bay, and that some of these may have so nearly crossed it as to leave only a sufficient channel for the outlet of the river water; but that the magnitude of the lake thus formed would not be so great as the tradition indicates, unless the waters were backed considerably over the plains around Galway, which would have been the case had its level been only slightly raised.

He found a popular opinion prevailing that the Aian Islands are the remains of a great barrier, but there is no present evidence supporting this.

Mr. W. H. Baily, M.R.I.A., F.G.S., read a paper on some Additional Remains of Labyrinthodont Amphibia and Fish found in the Jarrow Colliery, near Castlecomer, County Kilkenny. He illustrated his remarks with well drawn diagrams, and exhibited some of the specimens clearly defined in the coal, showing the vertebræ, head, fins, &c. Some of the reptiles were 3 feet 7 inches in length, and the fish specimens were beautifully marked in the matrix.

Mr. W. Pengelly, F.R.S. read the fourteenth report on the Exploration of Kent's Cave. He mentioned that the cave was situated a distance of one mile eastward of Torquay, and half a mile distant from the bay. It was beneath a hill 250 feet high. The deposits from time to time were black mould, in which were found sheep remains; under that stalagmite, and then cave earth, in which the bones of hyænine were discovered; then crystalline stalagmite and breccia, as yet the most ancient deposit found in the cavern. In the two latter the bones of bears only were found. The hyænine bones were the most numerous. Only one example of cave lion and one of fox were found here. Mr. Pengelly exhibited a number of specimens of jaw-bones and teeth of

the hyena, of the bear, some flint instruments, and a remarkable quartzite discovered in the cave during last year. The report contained an account of the explorations carried during the year. At the end of July, 1878, the two reaches only had been explored. Its floor was found to be a complete pavement of blocks of limestone, some of considerable size. The chamber measured about 30 feet from north to south; from 7 to 13 feet from east to west, and from 8 to 13 feet from the roof to the bottom of the cavern. The only objects of interest found in the chamber were four pieces of bone, which occurred at depths exceeding a foot, and a lump of oxide of manganese. The recess near the junction of the two reaches was, in proportion to its capacity, much more productive.

Mr. Isaac Roberts, F.G.S., read a very instructive paper "On Experiments on Filtration of Sea Water through Triassic Sandstone."

Mr. W. Pengelly, F.R.S., read a paper "On the Relative Ages of the Raised Beaches and Submerged Forests of Torbay."

Mr. V. Ball, M.A., gave a description of a new Geological Map of India which is soon to be published, with a manual of the geology of that country. Mr. Ball stated that his investigations in India had converted him to the glacial theory as exemplified in the boulders he had seen.

Professor Williamson, Owens College, Manchester, read a paper with regard to coal measures.

The President gave a short account of some fossils from the Northampton Sands, which, he said, formed an important part of the oolites, which had been described in papers published by the Geographical Society of London.

Mr. J. Nolan, M.R.I.A., read a paper "On the Metamorphic and Intrusive Rocks of Tyrone."

Mr. Sterry Hunt, LL.D., F.R.S., read a paper "On the Origin and Succession of Crystalline Rocks." The author's researches into the composition and structure of the crystalline rocks, conjoined with his studies of the chemistry of natural waters, led him, in 1860, to reject the hitherto received view of the epigenic or metasomatic origin of serpentine, steatite, chlorite, and similar rocks, and to maintain their derivation from silicates formed by chemical processes and deposited in the water of lakes or seas. This view he soon after extended to the various other exceptional rocks

found in crystalline formations which it was, in 1864, asserted had been "formed by a crystalline molecular rearrangement of silicates generated by chemical process in waters at the earth's surface."

In continuation of the same subject, a paper was read by Dr. Hicks on some new pre-Cambrian areas in Wales.

Mr. E. T. Hardman, F.C.S., read a paper on "Hullite," a hitherto undescribed mineral. He said this mineral occurs in abundance at Carnmoney Hill, near Belfast, in the basalt forming the neck of a miocene volcano. It has never been described as analysed, and has been referred to in the Survey maps and labelled on the Survey collections as obsidian, doubtless from its black colour and waxy lustre. In physical character it somewhat agrees with the chlorophaite of Maculloch, but is entirely different in composition, which more resembles that of delessite: from this, however, it differs essentially in colour, hardness, streak, and specific gravity, but it appears on the whole to belong to the ferruginous chlorite group. Physical characters—Colour, velvet black; hardness, 2; brittle; lustre, waxy to dull; very slightly affected by acids: occurs at Carnmoney and Shane's Castle, near Lough Neagh. Its most remarkable characteristics are its low specific gravity, and its resistance to the blowpipe—both curious points, considering the large quantity of iron it contains. The author proposed to call the mineral Hullite, after Professor Hull, in commemoration of the valuable work he has done in elucidating the microscopic mineralogy of the basalts of Ireland. Professor Hull has examined the microscopic structure of the mineral, and of the rock in which it occurs. Under the microscope it is of an amber brown colour, nearly opaque. It permeates the whole rock, filling the interstices, and enclosing the other minerals. It appears very much to assume the character of chlorite, and is undoubtedly a distinct mineral, and not a product of alteration.

Prof. E. Hull, M.A., F.R.S., Director of the Geological Survey in this country, gave a short account of the progress of the Geological Survey of Ireland from its commencement in 1832, under the late General Portlock, R.E., down to the present day, stating that the whole country south of a line drawn roughly from Larne on the coast of Antrim to Sligo had been surveyed, while 160 sheets of the geological map, on a scale of 1 inch to the statute mile, had been published. Along with these had also been issued 78 separate explanatory memoirs describing the structure and palæontology of

126 sheets. It had been found necessary to revise the geology of the Leinster and Tipperary coal-fields, the carboniferous trap-rock of the County Limerick, and the south-east portion of the country, including parts of Wicklow and Wexford. The coal-fields of the North of Ireland had also been surveyed and published in maps both on the 6-inch and 1-inch scales; and it was also intended that the districts of the County Antrim containing pyrolitic iron ores should be illustrated by maps on both scales. The district still remaining to be examined included the greater portions of Donegal, Tyrone, Fermanagh, Sligo, and Antrim.

The President said the object of these Surveys was to make the public at large thoroughly acquainted with the geology of the country in which they resided. Maps were carefully drawn, and memoirs published from time to time in illustration of the maps; but unfortunately, so far as the diffusion of knowledge was concerned at the present time,—not owing to any prohibition of the Geological Survey, but owing to some mistaken view on the part of the Treasury,—prohibitive prices were placed upon the geological memoirs. He had seen small pamphlets priced at 16s. or 17s., though these pamphlets were printed and published at the public expense for the benefit of the public. He held in his hand a very small pamphlet, which was published at 9s. He did not think a false economy of this kind ought to be suffered to go on without a protest on behalf of those who were interested in geological progress. He therefore felt it right to make these remarks, in the hope that steps might be taken to bring this matter under the consideration of the Treasury, and point out how with the one hand they were lavishly spending money for the advancement of geological knowledge, and with the other withholding it from the public.

Dr. Sterry Hunt read a paper "On the Geological Relations of the Atmosphere." The author began by noticing the inquiries of Ebelmen into the decomposition of rocks through the influence of the atmosphere, resulting in the fixation of carbonic acid and oxygen, and discussed the question at length with arithmetical data. He inquired farther into the fixing of carbon from the air by vegetation, with liberation at the same time of oxygen, both from carbonic acid and from the decomposed water, the hydrogen of which, with carbon, forms the bituminous coals and petroleums. It was shown that the carbonic acid absorbed in the process of rock decay during the long geologic ages, and now represented in the form of carbonates in the earth's crust,

must have equalled probably two hundred times the entire volume of the present atmosphere of our earth. This amount could not, of course, exist at any one time in the air; it would at ordinary temperatures be liquefied at the earth's surface. Whence came this vast quantity of carbonic acid which must have been supplied through the ages? The hypothesis of Elie de Beaumont, who supposed a reservoir of carbonic acid stored up in the liquid interior of the planet, was discussed and dismissed. The gas now evolved from the earth's crust from volcanic and other vents was probably of secondary origin, and due to carbonates previously formed at the surface. The solution of the problem offered by the author is based upon the conception that our atmosphere is not terrestrial, but cosmical, being a universal medium diffused throughout all space, but condensed around the various centres of attraction in amounts proportioned to their mass and temperature, the waters of ocean themselves belonging to this universal atmosphere. Such being the case, any change in the atmospheric envelope of any globe, whether by the absorption or the disengagement of any gas or vapour, would by the laws of diffusion and static equilibrium be felt everywhere throughout the universe, and the fixation of carbon at the surface of our planet would not only bring in a supply of this gas from the worlds beyond, but, by reducing the total amount of it in the universal atmosphere, diminish the barometric pressure at the surface of our own and of all other worlds.

Prof. W. King, D.S.L., contributed a paper "On the Age of the Crystalline Rocks of the County Donegal." He had succeeded in obtaining some true fossils in portions of the Innes Lower Limestone that have scarcely undergone any change. This was the first example, as far as he could ascertain, of an undoubted fossil having been detected in these limestones. The fact may be taken as evidence that their deposits and their associated argillaceous and siliceous masses are of the Lower Silurian Age, and it seemed highly probable that the more intensely metamorphosed rocks in the north-west division of Donegal belonged to the same geological period.

Biology. (Section D.)

The President of this Section was Prof. Flower, F.R.S.; Dr. Robert M'Donnell, F.R.S., presiding over the Department of Anatomy and Physiology, and Prof. Huxley over that of Anthropology. Our space will not permit us to give abstracts of the excellent addresses of these gentlemen, or of the papers brought before the Section.

Prof. Sir Wyville Thomson presided over Section E (Geography): his address was listened to by a crowded audience. Prof. Ingram, LL.D., presided over Section F (Economic Science and Statistics); and Mr. E. Easton, C.E., over Section G (Mechanical Science).

At one of the meetings of the Geographical Section Sir Wyville Thomson read a paper "On the Progress in the Official Report of the *Challenger* Expedition." While the ship was at sea their time was entirely devoted to the registering of observations, and cataloguing, labelling, and storing specimens. With regard to the destination of the collection he proposed that in the first place each specialist should be required to set aside all unique specimens, and the most complete series possible of all species of which there were duplicates, which should be sent to the British Museum, and that afterwards duplicates should be arranged in sets and distributed to museums at home and abroad. From what he saw at present this difficult Report of the Voyage of H.M.S. *Challenger* would extend to from fourteen to sixteen quarto volumes of 500 or 600 pages. The whole would be illustrated by about 1200 plates and many woodcuts and photographs. The map of the first volume was nearly completed, and the charts or ship's course and the sections showing the natural distribution of ocean temperature. The second volume will consist chiefly of tables, and will include a report on the magnetic observations met during the voyage, drawn up under the superintendence of the hydrographer of the Navy, and a detailed report on the meteorology prepared by Capt. Tizard. Another volume would contain the discussion of the nature of the bottom, the composition and specific gravity of sea-water and the composition of its gases, and a number of other general matters; and the remainder of the book will be occupied by a series of memoirs by different authors on the various groups of animals which constitute the deep-sea fauna.

NOTICES OF BOOKS.

Conferences held in Connection with the Special Loan Collection of Scientific Apparatus at South Kensington in 1876. London: Chapman and Hall.

THESE Conferences originated in a letter addressed by Lord Sandon to the Presidents of the various Learned Societies, in which it was suggested that the value of the Loan Collection of Scientific Apparatus then gathered together at South Kensington would be greatly enhanced by demonstrations of the mode of working various instruments, and by papers on different subjects connected therewith. The Conferences commenced on May 16th and were continued until the 2nd of June. Five Sections were formed, each possessing a President and several Vice-Presidents. The Sections were respectively devoted to—1. Physics. 2. Mechanics. 3. Chemistry. 4. Biology. 5. Physical Geography, Geology, Mining, and Meteorology. The volume now before us relates to the two first in the list.

The Physical Section was presided over by Mr. W. Spottiswoode, and it numbered among its Vice-Presidents eminent Professors from Germany, Italy, France, and Holland. In the opening address the President enumerated some of the greater curiosities of the Collection:—A quadrant of Tycho Brahe, telescopes of Galileo, lenses constructed by Huyghens, a telescope of Newton, Sir W. Herschel's grinding-machines for specula, and a telescope which he constructed in his earlier days; also the original siderostat of Foucault, a compound speculum by the late Lord Rosse, the Kew photoheliograph, and the "compound microscope" of Zacharias Gaussen constructed in 1590. The original air-pump and Magdeburgh hemispheres of Otto von Guericke were shown; also an air-pump of Boyle, the compressor of Papin, Regnault's apparatus for determining the specific heat of gases, Fizeau's and Foucault's original revolving mirrors, Daguerre's first photograph on glass, and original electrical apparatus of Faraday, and Ampère.

The first address was delivered by Mr. William Huggins, "On Spectroscopy applied to the Heavenly Bodies other than the Sun." The spectrum of the nebula in Orion was compared with those of hydrogen and nitrogen; the spectrum of Sirius with that of hydrogen in a vacuum tube; and the spectrum of Arcturus with those of hydrogen, magnesium, and sodium.

Mr. Lockyer afterwards gave an account of the present state of spectroscopic research, specially in reference to the mapping

of spectra. Maps are now drawn to twelve times the scale of Ångström's map, and of course the mapping has become much more minute. Thus in Ångström's map only three lines are shown between H and H_2, while in the new maps no less than *ninety-nine* are inserted.

Mr. H. C. Sorby followed with an account of "Spectrum Microscopes and the Measuring Apparatus used with them."

Other papers were read—by M. Pictet, on "Ice-making Machines;" on "Compass Correction in Iron Ships," by Sir Wm. Thomson; "The Radiometer," by Prof. Wartmann, of Geneva; and "The Anemometer," by Mr. Fletcher.

At the second meeting of the Conference Dr. Tyndall described some of his remarkable experiments on the reflection of sound by layers of air of different densities, and on sensitive flames. Dr. Stone read a paper on "Just Intonation" in music, and on the limits of audible sound; and Mr. Bosanquet gave an account of his instruments for the attainment of just intonation. Prof. W. G. Adams then read a paper on Sir Charles Wheatstone's acoustical discoveries.

In a very able and detail article on the "Instruments contributed by Italy," Prof. Eccher discussed the various inventions and discoveries of Galileo, and the instruments of the Accademia del Cimento, so liberally contributed to the Loan Collection by the city of Florence. The position of Galileo in the history of the Sciences is too well known to need more than passing notice, but the work of men like Redi, Viviani, Marsili, Dati, and Borelli is often overlooked or forgotten. Let us glance at the labours of the last-mentioned of these men—the Neapolitan Borelli. "A mathematician, a physician, an astronomer, he occupied himself with all subjects, and thus supplied himself with ample materials for future discoveries. He studied the reciprocal actions of floating bodies (*galleggianti*), and discovered its theory; he was the first to observe the variations of the barometer with the changes in the atmosphere; he considered the question of the freezing of water; he planned the experiments which were decisive against the idea of the positive lightness (*leggerezza positiva*); he measured the greatest expansion of air freed from surrounding pressure; he determined the weight of air compared with water; he suggested the famous experiment with the silver ball, to test the compressibility of water; and another experiment on the propagation of sound (*in vacuo*); he studied the contraction of various liquids in cooling; and in the researches on the velocity of propagation of light he was the first to construct the heliostat (*eliostata*);" . . . he also made various astronomical discoveries; he was the first to observe the *vena contracta*, and he devised new experiments to illustrate Galileo's idea of the fall of bodies in a vacuum.

On the occasion of the next Conference Mr. Dewar described his *Charcoal Vacuum*, which he produces by placing charcoal in

a tube, and exhausting by means of a mercurial air-pump at a red-heat. When this has been completed the tube is sealed up, and the last trace of mercury vapour, gas, sulphuric acid, and other impurities are absorbed by the charcoal, and in a few minutes the electric spark refuses to pass through the vacuum. A very good vacuum may also be made by filling a tube with bromine vapour, and absorbing it by means of charcoal. Prof. Rijke gave a very interesting account of the historical instruments from Leyden, which included the first compound microscope made at Middleburg, by Hans and Zacharias Gaussen, before 1610; various mechanical contrivances of S'Gravesande for illustrating the velocities of falling bodies; and lenses constructed by Huyghens.

The Mechanical Section of the Conference was presided over by Mr. C. W. Siemens, and among the Vice-Presidents were General Morin, Director of the Conservatoire des Arts et Metiers, and M. Tresca, the Sub-Director. The President's Address and several of the earlier papers relate to the subject of measurements—linear, superficial, solid, electrical—and of time. M. Tresca communicated a very important paper "On the Flow of Solid Bodies," embodying the results of many years of study and research; Mr. Barnaby, Chief Constructor of the Navy, a lengthy and valuable paper "On Naval Architecture;" and Mr. Thomas Stevenson described the more important improvements which have lately been made in lighthouses.

The subject-matter of this volume is most admirable, and the works cannot fail to be frequently consulted by men of Science.

A Handbook of Practical Telegraphy. By R. S. Culley. Seventh Edition. London: Longmans and Co. 1878.

This well-known work, which has been revised and considerably enlarged in this edition, contains an account of electric telegraphy in all its forms. Commencing with the sources of electricity, the author passes on to a consideration of the laws of the current, static and dynamic induction, atmospheric electricity, and earth-currents. The construction of telegraph lines, the management of circuits, and the apparatus used for signalling are then discussed; a long section is given to submarine telegraphy; and recent inventions, including the telephone, are finally discussed.

This work will undoubtedly continue to maintain the high position which it has so long enjoyed.

Natural Philosophy for General Readers and Young Persons. Translated from the French of GANOT, by E. ATKINSON. Third Edition. London: Longmans and Co.

THIS work has not been much enlarged, but it has received the very useful additional feature of a series of questions systematically arranged in reference to the corresponding parts of the book, which must greatly enhance its value, both to teachers of Science and to self-taught students.

Electric Lighting. A Practical Treatise, by HIPPOLYTE FONTAINE. Translated from the French, by PAGET HIGGS, LL.D., Assoc. Inst. C.E. London: E. and F. N. Spon. 1878.

THIS work is divided into twelve chapters, which treat of the Voltaic arc, electric lamps, magneto-electric machines, the motive power they absorb; the industrial applications of the light to manufactories, lighthouses, ships, and forts; the cost of electric lighting; lighting by incandescent tubes; and, finally, of the divisibility of the electric light, The light was first applied to lighthouses in 1863, at the lighthouse of Le Hène, near Havre, and the light (produced by an "alliance" electro-magnetic machine) was found to penetrate 8 kilometres further than an oil-light, while in foggy weather the range of the light was twice as great. There now exist electric lighthouses in France, England, Russia, Austria, Sweden, and Egypt, and the French Government are about to try the effect of a Gramme machine, giving a light equal to that of 2000 Carcel burners. Formerly the light of 100 Carcel burners required the expenditure of 3horse-power, but M. Gramme has succeeded in producing a light of 450 burners with an engine of 2 horse-power. As to the cost, the lighting of the Rue Impériale, in Lyons, with 60 Bunsen elements, was found to cost 3·55 francs per hour. An interesting table will be found (p. 164) giving the cost of various sources of light, from which we learn that the cost for 4000 burners per hour is estimated as follows:—

Wax candles	132·00 francs.
Stearine	98·40 ,,
Tallow	56·40 ,,
Colza oil	28·00 ,,
Voltaic battery	24·00 ,,
Petroleum oil	21·60 ,,
Shale oil	18·72 ,,
Oil gas	10·00 ,,
Gramme machine with steam motor ...	1·78 ,,
,, ,, ,, hydraulic power	0·44 ,,

Thus under the most favourable conditions the Gramme machine light is 300 times less expensive than the light of wax candles. It must be borne in mind, however, that interest and wear and tear ought to be charged upon the machinery.

An exact comparison of the relative cost of gas and electric lighting is given in the following tables for a spinning-mill of 800 looms.

First, in the case of the gas-lighting :—

Number of burners	415	
Number of hours of night-work per year	500	
Cost of introducing gas	12,000	francs.
Price of cubic metre of gas	0·25	franc.
Cost of gas per year	5486·85	francs.
Interest 12,000 francs, at 10 per cent...	1200·00	,,
Maintenance of apparatus and contingencies...	263·00	,,
Total cost of gas-lighting per year	6950·10	,,

The corresponding electric lighting requires :—

Six Gramme machines, at 1500 francs ...	9000	francs.
Six regulators of 300 burners, at 450 frs.	2700	,,
Wires and mounting...	1300	,,
Twelve horse-power steam motor	8000	,,
Total cost of apparatus	21,000	,,

Working expenses :—

Consumption of electric carbons, 240 metres, at 2·5 francs	600	francs.
Consumption of coal, 10 tonnes, at 30 frs.	300	,,
Interest on 21,000 francs, at 10 per cent	2100	,,
Annual maintenance and contingencies...	1600	,,
Total cost of electric lighting per year	4600	,,

"The electric light in this case costs annually 33 per cent less than that by gas, gives six times more light, and suppresses all danger of fire."

The light emitted by Geissler's tubes has been found to be of such slight intensity that they are practically useless even for powder-mills and gunpowder-works. The divisibility of the electric light, as employed by Jablochkoff in 1877, will apparently lead to a greater introduction of the use of this kind of light. "By the term 'divisibility of the electric light' we do not mean the production of several intense lights by means of one machine or battery, but simply the maintaining of a few small luminous centres, each equal to 1 to 15 Carcel burners."

M. Fontaine's work will be read with interest by all who are concerned in the application of electricity to lighting purposes. The book is well illustrated, and the translation has been carefully made.

The Human Eye; its Optical Construction Popularly Explained. By R. E. Dudgeon, M.D. London: Hardwicke and Bogue. 1878.

This work commences with an account of various instruments which help to illustrate the mechanism of the eye; lenses are discussed, and the refraction of light by lenses of different form and curvature. The eye is compared to a photographic camera, and various sectional diagrams are given to illustrate the views expressed. It is asserted that Külme has found that the image of an object thrown upon the retina during life remains visibly impressed on that membrane after death. The minute structure of the crystalline lens receives illustration; also the conditions of long- and short-sightedness. Clossat long ago pointed out the fact that the curvature of the crystalline lens is not that of a sphere, but of an oblate spheroid. Dr. Dudgeon proposes the use of *air* lenses for the use of divers under water. Of course an air-lens ceases to be a lens as soon as it is out of water. An interesting account is given of subaqueous optics and effects—among them the effects observed by a diver furnished with air-lens spectacles, who is resting on the bottom of a bath, full of clear water, with a perfectly unruffled surface. The eyes of fishes are discussed, and diagrams are given of the lenses of the skate and turtle. Dr. Dudgeon believes that the lens possesses a "rotation movement" in accommodation for near vision. "If the transition from near to distant accommodation takes place in the dark, there occurs, as Czernak has remarked, a sudden flash of light in the eye, which he calls a *phosphine*. This phenomenon is, I believe, caused by the sudden springing back of the lens to its normal unaccommodated position, communicating a shock to the retina whereby the sensation of light is evoked,—just as a slight blow on the eye will produce the sensation of a flash of ordinary light. At the same time the sudden relaxation of the ciliary muscle, or tensor chloroideæ, permitting the striated chloroid membrane to resume its position, will intensify the shock that produces the flash."

The work is clearly written throughout, and embodies the results of the most recent German researches on the subject, and it will be welcomed alike by the old and the young physiologist.

Light. A Series of Simple, Entertaining, and Inexpensive Experiments in the Phenomena of Light, for the Use of Students of every Age. By ALFRED M. MAYER and CHARLES BARNARD. "Nature" Series. London: Macmillan and Co. 1878.

THIS work describes, in simple language, a number of experiments illustrating the principal properties of light, by means of a beam of sunlight admitted into a dark room, and various contrivances. The experiments are highly ingenious, and, although in many cases insufficiently explained, the young student cannot fail to learn a good deal from the book. As an example of the effective experimental method employed, we may specially mention the device for illustrating the refraction of light, figured and described on page 46.

The book is specially designed "to give to every teacher and scholar the knowledge of the art of experimenting."

The Devil Demonstrated. By A PHYSIOLOGIST. London: Printed for the Author, by G. J. Ogden and Co.

WE have here a curious and highly original work, written ten years ago, and now published anonymously for fear of the tea-tables. The author, it should be premised, is not a materialist: he distinctly admits the existence of the Deity, and of an immaterial, supra-vital, responsible principle in man, not perishing with what is commonly called death. He recognises, moreover, the authority of the Christian Revelation, and in seeking to establish his doctrine he appeals to St. Paul against the authority of Milton, a writer whose glosses on the Scriptures have—in England at least—been popularly identified with the Sacred text, and are, we believe, to no small extent responsible for the antagonism which in some quarters still prevails between Religion and Science.

The author contends, in brief, that the Devil is neither a person nor a spirit, but an evil principle connected with the flesh, which lives and dies with that flesh, not found in man alone, but in every animal or vegetable form of matter. "Where there is force acting upon matter, there is the Devil"—a formula which would of course comprehend inorganic substances as well as plants and animals. "Wherever there is any evil principle, anything which works injury, the Devil, or evil, is there present, as much as in man."

This view is expounded in the form of a dialogue between a Doctor, a Friend, and a Patient, introduced by the latter, and who here is supposed to represent the unscientific British public.

This typical hearer receives the novel doctrine very complacently, considering that he has just declared that he "knows nothing of modern science, and looks upon it with horror," that he "cannot bear to meet a man of science," and that he has "read some of the pestilent and heretical works lately issued."

In the argument which the author brings forward we find, as one step, an account of atoms in which it is asserted "we know that they are formed of two distinct parts; that they are spheroids, having a dense axis and a less dense equator. For instance, the axis of the atom of oxygen is formed of ozone and the equator of antozone; the atom of water has oxygen for its axis and hydrogen for its equator." How an atom, which is *ex hypothesi* indivisible, can yet be formed of two distinct parts, more or less dense, it is difficult to conceive. Allowing, however, the author to substitute the term "molecule" for "atom," we are still not satisfied. The very existence of antozone is too problematical for us to accept this theory of the constitution of the molecule of oxygen. But even if we accept the whole of the author's interesting demonstration, we utterly fail to see that it leads necessarily to the point at issue. Supposing that there are sources of evil existing "within man, and concomitants of his flesh," this by no means disproves the existence of an external author of evil, a parastatic spirit.

Further, the author's views are deficient in clearness: from some passages we should judge that he pronounces all Nature—everything consisting of matter acted on by force Devilish—evil. But from others we should gather that he would consider these attributes as restricted to matter and force when exerting abnormal, morbid, and injurious influences. Accepting this as the more rational view, we have still to ask where is the boundary between good and evil—especially in a physical view—to be drawn, and who is to decide? A storm that ravages our crops and sinks our shipping may at the same time purify the air and remove an epidemic. Is it, then, diabolical or non-diabolical, or a happy mixture of both? The author seems to us not to distinguish clearly enough between physical and moral evil, which may be perfectly independent of each other. For granting to the fullest extent Dr. Johnson's dictum that "every sick man is a villain,"—granting that a diseased liver, indigestion in any form, and no less the mediæval religious exercise of fasting, are the teeming sources of envy, "hatred, malice, and all uncharitableness," we must never forget that there is at any rate one shortcoming to which man is prone, almost in the exact ratio of his health and vigour. It is curious how completely modern moralists forget the distinction between "appetites" and "passions."

Should the author's views meet with acceptance they would not, we believe, prove necessarily antagonistic to a belief in man's responsibility, but they might favour the recrudescence of

mediæval asceticism, and of that contempt for matter and "the flesh" which has been so formidable a hindrance to man's intellectual and physical progress.

Elements of Chemistry, Theoretical and Practical. By W. A. MILLER, M.D., &c. Revised by CHARLES E. GROVES, Sec. F.I.C., F.C.S., &c. Part II.—Inorganic Chemistry. Sixth Edition, with Additions. London: Longmans and Co. 1878.

STUDENTS and teachers, young and old, will welcome the sixth edition of Part II. of Dr. Miller's well-known Manual, which this time is entirely revised by Mr. Groves, who assisted Prof. McLeod in the preparation of the fifth edition, published in 1874. During the last four years inorganic chemistry has made but little progress, both professors and students preferring to employ their talents and occupy their time with trying to cram an additional atom of oxygen or hydrogen into some unhappy organic radical that no one but themselves has ever seen, and that strongly objects to give hospitality to the intruder, rather than with one or other of the endless problems with regard to the commonest reactions that are hourly staring us in the face.

Although there are but few new facts to chronicle during the period mentioned, one of them at least is of very great importance. We of course allude to the discovery of gallium by M. Lecoq de Boisbaudran, and its very unexpected confirmation of Newland's and Mendelejeff's periodic law. The influence of this discovery on the theory of the relationship between the elements, first glimpsed by Prout, is a very important one, and it might, we think, have been more enlarged upon in the fifty pages which Mr. Groves has added to the sixth edition. An account of Davyum, too, is found in its proper place. Short accounts are given of Deacon's and Weldon's chlorine processes, but we have searched in vain for any notice of Mactear's sulphur regeneration process. The ammonia process for making sodic carbonate is briefly described, but we are not informed whether it is successful or not. If, as has been stated, the Island of Cyprus contains innumerable salt-springs, this process may play an important part in the regeneration of our latest possession.

Under Iron, the description of Danks's method of puddling by machinery; and short accounts are given of Crampton's and Henderson's processes. The account of Siemens's process is also enlarged—a remark that equally applies to the Bessemer process.

As in the fifth edition, Dr. Frankland's constitutional formulæ are introduced between brackets, to show that they are interpo-

lations into the original work. We are at a loss to see the necessity for this. Dr. Frankland's formulæ are far from being universally used by teachers, who find them cumbersome in use, and more apt to lead to blunders on the part of stupid students than the ordinary empirical formulæ. At present we really know little or nothing about the constitution of bodies, and in our opinion it would be better humbly to acknowledge our ignorance by giving up the use of more or less improbable constitutional formulæ in our text-books.

Flowers: their Origin, Shapes, Perfumes, and Colours. By J. E. Taylor, Ph.D., F.L.S., F.G.S., &c. London: Hardwicke and Bogue.

We have here not indeed a record of original research, or a formal treatise on phytology intended for the professed student of vegetable life, but an attempt to "place before that portion of the intelligent public who have the desire, but neither the time nor opportunity to make themselves acquainted with natural science, the charming and suggestive results of modern botanical investigation." To such a task the author brings unusual qualifications. An able and enthusiastic botanist, and fully acquainted with all the recent discoveries in natural history, we might well expect from his pen a work at once readable, thoughtful, and suggestive. Nor shall we be disappointed. The volume before us teems with interesting facts, described for the most part in clear language, and made more telling by the aid of numerous and well-selected illustrations. The reader who may feel disinclined to wade through original memoirs will find here, for instance, an account of the newly-discovered carnivorous plants, the wondrous story of the mutual relations between insects and flowers, and of the uses of colour and perfume to the latter. He will learn here something of the wonderful contrivance to prevent exclusive in-breeding, and secure occasional, if not frequent, crosses. He will find for what purpose and in what manner plants climb. Passing from individual phenomena to general truths, he will learn to take a broader and healthier view of the vegetable—as indeed of the whole organic—world than to consider it existing with exclusive reference to man.

Still we must own to a certain amount of disappointment in the perusal of Dr. Taylor's book. There is, in the first place, a considerable amount of needless and wearisome repetition. Thus the distinctive attributes of the two great groups of flowers, the anemophilous and entomophilous, are explained twice over,

on pages 15 and 149. The relations between flowers and insects are touched upon in almost the same words on pages 29 and 148. On page 15 we read—"Every cottager who has hung the gaudy-coloured paper fly-cages in his room, to prevent his clean white-washed roofs and walls from being dirtied by the common house-fly, has practically availed himself of the attraction which bright colours have for even these non-flower-loving insects." On page 174 the same idea recurs in almost the same words:—"In the brilliantly coloured paper fly-cages which he has been in the habit of hanging from the roof of his cottage, to save its clean white-wash from soiling, the cottager has practically taken advantage of the attractions which colour has even for the Diptera."

There are also certain peculiarities of expression which a little care in the revision of the press might have prevented. Thus in one passage we are told that "spectroscopic analysis has made it (the nebular hypothesis) more probably truthful than ever." Elsewhere there is reference to "a paragraph which Brongniart *made* in 1849;" and on page 184 we read—"Both them and the jonquils are remarkable for having a corona or tube within the flower."

As regards the subject-matter of the work before us, there are also certain points on which issue might be joined. Thus the author (p. 299) ranks humming-birds "among the latest products of Evolution." Mr. Wallace, on the other hand,* holds that "their extreme isolation from other forms, no less than the abundance and variety of their generic and specific forms, clearly point to a very high antiquity."

On page 19 we read that the *Sphinxes* (Sphinges) or hawk-moths "have not only long probosces, but slender bodies and hawk-like wings." To us the bodies of the hawk-moths appear thick in comparison with those of the generality of Lepidoptera.

The author, with many naturalists, considers that the bright colours of certain berries, &c., are designed to induce birds to partake of them. "It may be found that the colours of our wild berries are in this way as serviceable to the plants in obtaining for them distribution of bird-agency as those of their flowers have been in attracting those insects by whose aid these very seeds have been produced. . . . It may be that the very reason why the coloured succulent berries of some plants are uneatable by or poisonous to other animals than birds is a gain to them, in preventing their being swallowed by creatures in whose stomachs the seeds would be digested and assimilated. Singularly enough, with the increased size of our garden fruits produced through cultivation, there has often been developed a

* Tropical Nature, p. 148.

different habit on the part of our wild birds. They no longer swallow the cherries and plums whole, and so they content themselves by eating away all the juicy pericarp, leaving the stones hanging by the footstalks." This we may, indeed, see on every cherry-tree, but we may see it also on the wild cherry. It is not swallowed whole, but its small layer of pulp is carefully picked away from the stone. We must also remember that many Mammalia void the seeds of fruits undigested.

It is a curious fact that brilliant colouration in caterpillars and other insects should so often be a warning to birds that the species is not edible, whilst in fruits it is an invitation to a banquet. There is only one further passage to which we have space to advert. "The Romish Church," says our author, "authoritatively denounced the Copernical theory of the Universe, just as she has recently denounced Darwinism." Now that many clergymen of the Catholic Church have expressed themselves hostile to the doctrine of Evolution is indisputable. In this respect they have not been singular. Clergymen of the Church of England, ministers of the Scottish Church and of dissenting communities, have done the same. But that any formal and authoritative condemnation of "Darwinism" has been pronounced by the Holy See we have yet to learn.

Dr. Taylor's work is provided with an elaborate table of contents and an excellent index.

Annual Record of Science and Industry for 1877. Edited by Spencer F. Baird. New York: Harper Brothers. London: Trübner and Co.

This useful work has undergone a change of plan. The abstracts from scientific journals and from the Transactions of Societies, which formerly constituted its main feature, has been omitted, in consequence of the rapidly increasing quantity of scientific work done in the world, and in its place the summaries of progress of each science have been extended.

In biology no very striking advance during the past year is here recorded. Mr. Scudder, though from a different point of view, joins Mr. A. R. Wallace in objecting to the doctrine of Sexual Selection." Whilst admitting with Mr. Darwin that where the sexes differ in colouration the male is most beautiful, he contends that it is the female who "first departs from the normal type of colouring of the group to which the species belongs." He recalls no case where such a departure can be traced in the male alone. He points out that the males of certain butterflies possess peculiar cells, to which he gives the name of *androconia*. These are of great beauty and delicacy, but are

hidden among the others. Here, the compiler remarks, "the theory of Sexual Selection proposed by Darwin appears to fail just where it should aid us most." We certainly cannot contend that Sexual Selection can account for ornamentation in an invisible part. But as little will the doctrine of the old school of natural history—that beauty in plants and animals exists merely for the delectation of man—serve our purpose here.

Mr. Packard deprived a number of insects of all orders of their antennæ. He found that the hive-bee was more affected than any of the others operated upon. "The removal of the antennæ of this insect seemed to show that the sense of hearing may reside in the antennæ, while that of smell has its seat in the palpi (and perhaps the tongue) alone. It would also seem as if the antennal nerves were so continuous with the brain (supra-œsophagical ganglia) that they form as it were a part of it, their removal at a little distance from their origin producing such a shock to the ganglionic nervous system that the insect acts somewhat like a bird when deprived of its central hemispheres. In an ichneumon the sense of taste appears to be situated in the ends of the palpi. In the butterflies the sense of taste, as well as touch, is situated in the spiral tongue. Spiders, on losing their maxillary palpi, seemed to be affected much as insects on the loss of their antennæ."

In view of the great shock to the nervous system here admitted we should feel somewhat sceptical as to the value of the indications afforded by such a method of experimentation. Our own observations—made on presenting to insects a great variety of bodies, attractive and repulsive—lead us to the conclusion that the antennæ are the organs of smell. The following experiments, performed by Père Montrousier, of New Caledonia, supports the same view:—He coated a weevil, *Octhorinus cruciatus*, over with wax, save the tips of the antennæ. On presenting to it oil of turpentine it was much agitated, and endeavoured to escape. Another specimen, on the contrary, had merely the tips of its antennæ coated with wax, and it remained perfectly indifferent to all strong-smelling substances.

Dr. Hartlaub's researches on the birds of Madagascar strengthen the case of those who consider that island too distinct in its fauna from the adjoining mainland to be regarded merely as a sub-region of the Ethiopian region. In Madagascar there occurs not one of the forms most characteristic of Africa.

Sir John Lubbock, in his latest experiments, finds that ants recognise old companions, and receive them amicably, even after a year's separation, while strangers are almost invariably attacked.

Prof. A. Gray thus states "Nature's golden rule for flowers: get fertilised; cross-fertilised if you can; self-fertilised if you must."

A Science Primer. On the Nature of Things. By J. G. MACVICAR, A.M., LL.D., D.D. Edinburgh and London: W. Blackwood and Sons.

DR. MACVICAR uses the word "Primer" in a somewhat peculiar sense. It is generally taken to signify a plain, simple, elementary treatise which a mere tyro may comprehend, and which, passing over controversial matters, deals merely with what is fully established and generally recognised. From all this the "Primer" before us differs widely. It contains much which we, after a life devoted to science, find ourselves unable to understand clearly; much that is, to say the least, doubtful, and much that sadly lacks demonstration. The very methods of science are, in our opinion, completely ignored, and the results seem to us indefinite and intangible. The author tells us that his work is "grounded on the belief of [in ?] an Almighty Being possessing unity, omnipresence, and ever-blessedness, and awarding existence to a creation for the sake of manifesting Himself and extending blessedness beyond Himself, and, in a word, to be a mirror of Himself so far as the finite can bear a likeness to the Infinite. After setting out with this cosmical law of *assimilation*, by its aid alone bearing on only one kind of created substance or energy ('mind-stuff'), he deduces the creation of the world of Spirits, and as their home the Universal Ether or medium of light. Then, as a beautiful cloud-work in the azure of the Spirit World, he gives the genesis of Matter and the molecular system, culminating in this planet in the construction of the myo-cerebral organism, whose characteristic function is to construct a powerfnl tissue of organised ether or the matter of light, which being unified in its focus of vital action into an element of energy so powerful as to have recovered the primal attribute of energy—namely, mental power—is a spirit." In consideration for scientific men he advises them to turn first to the latter part of the work, where he thinks that he has verified his theory "by a detailed appeal to natural phenomena, and experiments in physics and chemistry." Thither accordingly we proceed, in the hope of finding a key to what has gone before. But on arriving at our destination we find experimental evidence is wanting. There are assertions, but they lack demonstration. We read, p. 65, "Thus with regard to silica itself, its molecular structure, as obtained by our method, shows that it is not destined to remain for ever dead, giving to nature nothing but barren rock and sand. Every atom of it is capable of development into coupled atoms of oxygen and carbon, and a tetratom of hydrogen. This the actual chemistry must assent to, thus far at least as to admit that their atomic weights are the same.

$$\text{"Silica, at weight 60} = \begin{Bmatrix} 2O = 32 \\ 2C = 24 \\ 4H = 4 \end{Bmatrix} = 60.\text{"}$$

We will not here object that the atomic weight of oxygen is considered to be not 16, but 15·96, and that of carbon not 12, but 11·97. But we must certainly enquire whether Dr. Macvicar assumes it as a general truth that if the atomic weight of an element equals the sum of the atomic weights of certain other elements, it is to be considered as capable of resolution into the latter? We shall be ready to accept the author's view of the composition of silica so soon as he shall have succeeded in resolving it into oxygen, carbon, and hydrogen, or in forming it synthetically by the union of these elements.

Concerning ammonia the author entertains also peculiar views. He writes:—"The experimental chemist experiences no greater difficulty in his pursuit of exact analysis than to obtain possession of a considerable quantity of mere or pure water. Let him distil water over and over again, if only the distillate have stood for a time he finds ammonia in it. This phenomenon the popular chemistry which maintains the solidity, simplicity, and non-developable character of the sixty-three chemical atoms, is obliged to ascribe to the previous existence of organic matter in the water." This state of things, which he thinks "cannot but be provoking to the chemist," he accounts for by pronouncing ammonia "a product of pure water itself, and immediately after common vapour itself a primeval substance." Before Dr. Macvicar exults over the "popular chemistry" let him remember that ammonia is not difficult to detect in the atmosphere, and cannot well escape being absorbed by water on prolonged standing, even if preserved in bottles with the best-fitting stoppers. Can he bring forward a case where a competent experimentalist has obtained water free from ammonia and from organic matter, has then sealed it up before the lamp, and has then on opening it—after the lapse, say, of a year—found it ammoniacal? If the author can make ammonia out of water, not merely honour will be his, but wealth such as the world has not yet dreamt of. Will he neither tell us how it is to be done, nor, if that is impossible, point out where Nature is doing it in "a considerable quantity"?

It will have been perceived that Dr. Macvicar does not recognise the ordinary elements. He says—"There are between sixty and seventy (kinds of) particles of matter which chemists down to the present day have not succeeded in decomposing, and which, strange to say, on this negative evidence they have concluded to differ from all the thousands of other (kinds of) particles which in the progress of analytical chemistry they have succeeded in decomposing, and hold to be simple and solid unities or true natural atoms of matter."

The author must surely be aware that the definition of an element, in chemical language, is merely a body which we have neither been able to compose nor to decompose. "Strange to say" he goes on to show why these elements should "differ

from all the thousands of other particles" which have been decomposed. "Surely," he exclaims, "it is most improbable that human creatures in this small planet should be able to accomplish in their chambers the destruction of particles on which the economy of Nature out in the Universe has mainly been devolved." Here, then, is a formal admission that these elements are after all naturally distinguished from their compounds.

Our chemical readers, however, will not thank us for further pursuing the examination of a book which is rarely tangible, and which formally discourages the appeal to experiment, holding up the early physicists of Greece as examples, and recommending us to examine facts with the mental eye rather than with that of the body. Such works appear from time to time, written generally by men who have little practical acquaintance with their subject, and pass away without having contributed anything to the stock of human knowledge or to our means of research.

A Practical Treatise on the Steam-Engine. By ARTHUR RIGG. London: E. and F. N. Spon. 1878.

THIS work is exactly what is described by its title. Written in an easy style, and with an avoidance of too much technicality, its contents may be readily understood by the young student or the mechanic, to whom it appears to be addressed rather than to the more scientific investigator of theories, and yet its pages may with advantage be consulted by the latter, for it is the result of careful and conscientious practice based upon scientific reasoning and knowledge. In the commencement the different measurements required in the constructive dimensions of the steam-engine are considered, and it is shown how, for this purpose, the English units of the foot and inch are better adapted than the French metre. Following this, the laws which govern matter in its various forms and motions are investigated under the different headings of Velocity, Momentum, Work, Power, and Centrifugal Force, each of which is carefully but clearly explained.

Having thus disposed of the definitions connected with the main subject, we are next introduced to the horizontal steam-engine, with which, Mr. Rigg truly says, for compactness and easy accessibility to all parts no other type of steam-engine can compare. There are, however, different classes of these engines made, some for sale, others for work, and it is to the latter only —in which the object of the designer has been to apply the discoveries of Science, and practice of experience, to means for the most economical production of power—that the attention of

the reader is directed. In this chapter the details of all the principal parts are explained, and freely illustrated by numerous plates. Then follow particulars of the construction of the more important parts, including pattern-making, moulding, and casting, for the cylinder and cylinder-cover, in which the proper allowance for contraction on cooling is considered. The piston and piston-rod, and the proper method of their construction, are also explained, and the slide valve with its connected parts receive a share of attention commensurate with their importance. Then follow explanations regarding the other parts of the engine, which need not be detailed here; and indicators and indicator-diagrams are next discussed and explained, and after this the influence of the velocity of reciprocating parts of steam-engines.

The concluding chapter consists of a brief *résumé* of the principal theoretical considerations in the modern science of thermodynamics which have a direct bearing on the many points, referred to in early chapters, in the construction of steam-engines. Here the mechanical equivalent of heat is considered but briefly, and we cannot avoid an expression of opinion that this subject might with advantage have been more fully dwelt upon; it is, however, dismissed in two pages, and, in fact, the most important questions connected with it are not even touched upon. It is true that of this chapter it is said, in the Preface, that it may almost be considered as an Appendix, for that it is merely intended as an outline of the views generally received among Engineers at the present time on the relationship which exists between heat and work; but we should have preferred this portion of the Appendix being more fully explained. A greater amount of space is given to the explanation of Isothermal and Adiabatic Lines; and a few brief remarks on the amount of expansion that can be made practically useful bring the book to an end.

That important addition to all works likely to be of use for purposes of reference, viz., a good index, contributes in no small degree to the value of the present work. The illustrations, of which there are ninety-six plates, besides numerous woodcuts interspersed with the text, are well drawn and carefully printed. Indeed the whole volume, from beginning to end, is got up in a style quite in keeping with the character of the work itself, which leaves little to be desired; and on the whole it may be safely stated that it embodies a fair and carefully drawn record of the best practice as it exists at the present day, so far as fixed engines are concerned. The subject of locomotives and marine engines has, however, been purposely omitted, for the reason, as is explained, that they have already been pretty fully discussed in other works.

Sanitary Engineering. A Guide to the Construction of Works of Sewerage and House Drainage, with Tables for facilitating the Calculations of the Engineer. By BALDWIN LATHAM, C.E., F.G.S., F.M.S., &c. Second Edition. London and New York: E. and F. N. Spon.

PERHAPS the greatest difficulty in the way of the sanitary regeneration of a city, a district, or an entire country, lies in the fact that it requires the co-operation of a number of distinct professions, none of which can be safely dispensed with. The chemist has to investigate the composition of polluted waters, to point out in what respect and in how far they differ from a natural standard, and to adjudicate on the efficiency of the means or processes proposed for their purification. The medical practitioner is required to trace out the effects upon public health of impure air and water, whether the latter be used in diet or merely allowed to exist beneath and near human habitations. The practical agriculturist must pronounce on value of the schemes put forward for the utilisation of sewage. Passing over the functions of the jurist and the statistician, we come to the duties of the engineer, which though last are assuredly not least. He has to devise and carry out methods both for introducing pure water into our cities and villages in the most efficient manner, and without becoming contaminated on the way, and, on the other hand, to remove from the vicinity of our dwellings all polluted liquids, so that they may have the least opportunity of diffusing contamination. This involves the construction of water-works, the laying down sewers and drains, with all their accessories, such as ventilators, traps, &c. There is, curiously enough, one engineering problem in connection with this subject the solution of which we do not remember to have seen even attempted. This is—Suppose a given flow of sewage is treated by any precipitation process, to find the shape and size of tanks in which the precipitated matter shall be most quickly and completely separated from the effluent water.

Mr. Baldwin Latham's work contains some very curious information on sanitary laws and customs in antiquity. It is salutary, though perhaps humiliating, to learn that in this boastful nineteenth century we are scarcely more advanced in practical hygiene than were our predecessors some three thousand years ago. Rome was probably better supplied with water than any city of the present day, and its citizens would scarcely have erected statues in honour of the inventor of monopolist water-companies. The author ascribes the worship paid by the Ancient Egyptians to the Scarabæus, or "Sacred dung-beetle" (*Ateuchus sacer*), to their acquaintance with its sanitary services.* On the same principle it might perhaps be argued that

* See Quarterly Journal of Science, vol. vi., p. 163.

the Ancient Hebrews, in dedicating flies to the Evil One, were influenced by a knowledge of their function as disseminators of disease and death. We learn that sewage-irrigation was practised in Jerusalem. The blood of the sacrifices offered in the Temple, and doubtless the other nuisances of the city, were flushed down with abundant water into the Valley of the Kedron, and were there received in subsidence-tanks. The solid matter was collected and sold for manure, and the effluent used for irrigation. It must be remembered that in a climate like that of Judæa, where the rainfall is scanty and the evaporation excessive, a supply of water is often the one thing needed to convert a desert into a garden. The water-closet, which is often considered as a modern and an English invention, and is often spoken of in France as "cabinet Anglais," is traced back to Asia. "They were introduced into Rome during the Republic, and are noticed by several ancient writers. Those constructed in the palace of the Cæsars were adorned with marbles, arabesques, and mosaics. At the back of one still extant there is a cistern the water of which is distributed by cocks to different seats." In Ogilby's "Africa," a work published in 1670, these are described as being numerous in the city of Fez. Sir John Harrington introduced them into this country in the reign of Elizabeth, but, according to M. Roubo, they had been long used in France before becoming known in England. As a contrast we find that in our own days, in the sixteen years ending in 1862, fifty-one cesspools in Windsor Castle were abolished. These *foci* of disease and nuisance within the ancient palace of our monarchs varied in size from 12 feet by 8, and 9 feet in depth, to 3 feet in diameter by 6 feet in depth.

But indeed we are only beginning to throw off the heritage of filth handed down to us from the Dark Ages. Mr. Latham may perhaps exaggerate when he tells us that "for a thousand years there was not a man or a woman in Europe that ever took a bath." But it is certain that for a long time cleanliness and heresy were deemed to be closely connected. Even in our own days, in the south-eastern and south-western peninsulas of Europe, dirt is regarded as the characteristic privilege of the Christian as compared with the Turk or the Moor.

Among other subjects Mr. Latham discusses the vexed question of a single or a double system of drainage. He points out that the surface-water of our cities is almost, if not quite, as impure as sewage properly so-called. He shows that if the rainfall is entirely excluded from the sewers, the latter will require flushing. But, as the best arrangement, he seems to recommend "a system of sewerage combining the admission of small amounts of rainfall into the intercepting sewers of a town, while in time of heavy rainfall the comparatively pure surface-water should flow on to its natural outlet." The great arguments in favour of this plan are that it restores to the streams

water that is much needed, and greatly facilitates every process for the treatment of the sewage. One of the most telling arguments against irrigation, as ordinarily practised, is that in seasons of heavy rain, when the soil is least able to bear any additional quantity of water, the most is forced upon it by the swollen sewers. Where Mr. Latham's plan, or any similar scheme, is adopted, this objection falls away. Sewage-precipitation works are also much embarrassed by floods when the deposit is in danger of being swept out of the tanks and carried into the rivers.

The chapter on the sanitary appliances of a district, as affecting the quality and quantity of the sewage, contains some statements with which we cannot agree. That "in the sewage of a midden-stead town there is a larger proportion of urine present in a given volume of sewage than is found in a water-closet town" is simply impossible, and the "excess of chlorine," upon which so hazardous an assertion is built, is therefore no sure guide.

A large proportion of the matter in this book, though of little interest to the general reader, is certain to be most valuable to the engineering profession and to municipal authorities, who will find it a priceless manual of reference.

The Steam-Engine considered as a Heat-Engine. By JAMES H. COTTERILL, M.A., Professor of Applied Mechanics in the Royal Naval College. London: E. and F. N. Spon. 1878.

THIS work is represented, in the Preface, as a second edition of some Notes on the Theory of the Steam-Engine, published in 1871. It has, however, been so supplemented and added to as most considerably to enhance its value. The object of the present book is stated to be to study the process of the conversion of heat into work in steam-engines; and the experiments of Regnault, Raukme, and others, are not only repeatedly verified, but also worked out to their natural conclusions, aided by the further experience which has, since their days, been obtained on the subject.

In a chapter on the physical properties of steam it is explained that the "total heat of evaporation of water is the quantity of heat requisite to raise a pound of water from 32° to a particular temperature, and evaporate it at that temperature, while the latent heat of evaporation of water is the quantity of heat requisite to evaporate a pound of water at a given temperature." This latent heat diminishes as the temperature increases, approximately by rather more than seven-tenths of a thermal unit for each degree of Fahrenheit: this rate of diminution is, how-

ever, not exactly constant, but increases with the temperature. The density of steam is not at present exactly ascertained, but the general results of experiments show that the weight of a cubic foot increases nearly in proportion to the pressure, but at a somewhat slower rate.

In the next chapter, on the convertibility of heat and work, it is asserted that "energy when exerted is not destroyed, but simply transferred from one body to another." It is shown, however, what a very small proportion of the heat expended in the process of evaporation produces an equivalent of work,—hardly one-twelfth,—the greater part of the heat having been employed in producing changes within the water itself, in overcoming the molecular cohesion of its particles, which resists its conversion into steam. The heat expended is thus converted into two classes of work, viz., external work, or that which is appreciable to the senses, and internal work. In applying the foregoing reasonings to the steam-engine it is demonstrated that, in a non-expansive engine, only from $5\frac{1}{2}$ to $7\frac{1}{2}$ per cent of the heat expended is converted into useful work, but that the efficiency may be more than doubled by expanding the steam five times in the cylinder, and still further increased, though only to a small extent, by a further increase in the expansion.

Chapter IV. deals with physical properties of the permanent gases, in which the theory of a heat-engine worked with a *perfect gas*, under conditions of maximum efficiency, is considered, and it is explained that under certain conditions 56 per cent of the heat expended may be transformed into mechanical energy. We have next a consideration of the circumstances of "a perfect heat-engine," and here we find that "in the best possible steam-engine, unless the steam be superheated considerably, at least two-thirds of the whole heat expended is wasted, the waste arising from no fault in the construction or nature of the engine, but solely from the narrow limits of temperature within which we are restricted to work. Again, the consumption of steam in a perfect steam-engine is much less than that of an actual engine under the same circumstances, showing that faults in the construction of the engine or the treatment of the steam must exist, which, at least theoretically, are remediable."

The expansion of steam, the effect on engines receiving heat at varying temperature, the consequences of "clearance" and "wire-drawing," and the action of the sides of the cylinder and of water remaining after exhaust, are dealt with at some length in the succeeding chapters, whilst the last one is devoted to the application of the theory of the steam-engine, already discussed, in further detail to the working of steam-engines in practice. Here we learn that "Experience appears to show that 18 lbs. of steam per I.H.P. per hour is about the minimum consumption of steam commonly reached in actual engines; and the preceding calculations indicate that, in condensing engines, this is equiva-

lent to saying that about 13 per cent of the whole heat expended may be turned into mechanical work, or about 50 per cent of the heat which would be turned into work in a theoretically perfect engine working between the same limits of temperature." The average result, however, even in economically worked engines, is much less,

We have now, it is hoped, given sufficient particulars of the contents of this book to show its great value as a work calculated to lead the thinking mind to a study of the more important theories and principles connected with the steam-engine. Much more might have been said here, but the space available for a review is necessarily limited, and we can only now conclude this brief notice by strongly recommending the work before us to all more advanced students of steam and of the steam-engine.

Improvements in certain Iron-work. By Messrs. Hoopes and Townsend.

This little work not being provided with a title, we have been obliged to provide it with one of our own invention. It is a notice of the trade specialities of the firm from whom it proceeds—such as "key-stone" boiler-rivets, cold punched nuts, &c. It contains a Report, by Prof. R. H. Thurston, on the results of experiments performed at the Stevens Institute of Technology, in order to decide the comparative resisting power of "cold-punched" and "hot-pressed" nuts. The former, according to the figures quoted, showed a marked superiority.

The Speaking Telephone and Talking Phonograph, and other Novelties. By George B. Prescott. Fully illustrated. New York: D. Appleton and Co. 1878.

Mr. Prescott is already favourably known, both in this country and America, as the author of an excellent Manual of Electricity and Telegraphy: but we are sorry to say that the present work, although valuable in its way as a record of facts, is not calculated to add to his reputation as a scientific writer. It consists, for the most part, of verbatim reprints of most of the papers on telephony and kindred subjects which have been read before the different scientific societies of England and America during the last two or three years, loosely strung together, and interspersed with a few remarks from the author. These papers are all printed in the same type as the original matter, and as inverted commas

are placed only at the beginning and end of each of them, it is often difficult to know whether it is Mr. Prescott or some one else that is speaking in the first person without referring back several pages. The very Introduction itself is confused by the reprint of a speech delivered by one of the counsel at a recent telegraphic trial in New York. It is a very meagre account of the history of electrical discovery, which we cannot agree with Mr. Prescott in thinking either "interesting" or "valuable," seeing that exactly fourteen words are devoted to Faraday's discoveries in magnetic induction.

The first chapter is original, and gives us a clear and succinct account of the principles of sound; Reiss's musical telephone, and Gray's improvements on it; Gray's, Bell's, and Dolbear's articulating telephones; and Phelps's duplex telephone—the latter a very beautiful piece of apparatus, as far beyond Bell's trumpet-shaped instrument as a modern Westley Richard's central fire breech-loader is beyond a Joe Manton. Edison's carbon disk telephone is also described, but the book appears to have been published too early in the year to have included any account of the microphone.

Chapter II. consists of the paper read by Prof. Bell, in October last, before the Society of Telegraphic Engineers, with a few notes by Mr. Prescott. Chapter III. is made up of articles from the "Westminster Review," "Engineering," and "Chambers's Journal. Chapter IV. is a hotch-potch from various sources—such as "Silliman's Journal," "Poggendorf's Annalen," De la Rive's "Electricité," &c.—on the production of sounds by electricity. Chapter V. consists of Mr. Elisha Gray's papers on Telephonic Researches, read before the American Electrical Society or contributed to their Transactions. At the end we find both Mr. Gray's and Prof. Bell's original specifications, as filed by them at the New York Patent Office on the same day, *i.e.*, February 16, 1876.

Chapter VI. contains an account of Mr. T. A. Edison's telephonic researches, from his own pen, giving a most interesting account of his various discoveries and inventions, apparently written expressly for Mr. Prescott's work. Chapter VII. is a history of electro-harmonic telegraphy, read by Mr. F. L. Pope before the American Electrical Society in December last. Chapter VIII. consists of an abstract from a paper by Professor Dolbear, entitled "Researches in Telephony," in which he definitely claims to have been the first person to use a permanent magnet for vibrating the disk of a telephone.

In Chapter IX. Mr. Prescott once more resumes his task, and lucidly describes the improvements made in telephonic instruments by Messrs. Blake, Peirce, Channing, and others, in which he claims for the latter physicist the invention of the first portable telephone. Chapter X. is on the Talking Phonograph, and is almost entirely written by Mr. Prescott. The prophecies as to

what Mr. Edison's invention will accomplish in the future, and the extract from a particularly popular article in "Scribner's Monthly," are hardly worthy of a place in a serious scientific book.

As a piece of scientific exposition Chapter XI., on Quadruplex Telegraphy, is undoubtedly the best in the book, and is a tantalising proof of Mr. Prescott's ability to treat of such subjects. It is certainly the most thorough description of the wonderful improvements which have lately been made in multiplex telegraphy which we have yet met with.

Electric call-bells and the electric light receive attention in the two last chapters of the book. The last subject might, however, have been treated of at greater length, seeing the attention it is attracting in London and Paris. We should have been glad, for instance, to have heard more of Mr. Farmer's method of obtaining a number of lights from a single source, by using thin strips of platinum or indium, and raising their temperatures to a point slightly below that of melting.

The Index is far too small for a work containing so much matter.

In the chapters which are due to Mr. Prescott's pen alone, he proves to us with what lucidity he can treat a scientific subject.

The work contains over two hundred woodcuts, most of them of great beauty, and many of them far beyond anything that has yet been accomplished by our English wood-engravers in the way of scientific illustrations. Mr. Prescott also adopts the excellent plan of repeating a cut whenever it is necessary, instead of worrying the reader by frequent cross references. The general "get up" of the book is fully worthy the reputation of the firm by which it is issued.

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